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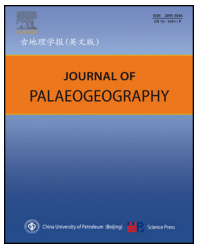


Lithofacies palaeogeography and sedimentology

# On palaeogeographic map


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ABSTRACT

The palaeogeographic map is a graphic representation of physical geographical characteristics in geological history periods and human history periods. It is the most important result of palaeogeographic study. The author, as the Editor-in-Chief of *Journal of Palaeogeography*, Chinese Edition and English Edition, aimed at the problems of the articles submitted to and published in the *Journal of Palaeogeography* in recent years and the relevant papers and books of others, and integrated with his practice of palaeogeographic study and mapping, wrote this paper. The content mainly includes the data of palaeogeographic mapping, the problems of palaeogeographic mapping method, the "Single factor analysis and multifactor comprehensive mapping method —— Methodology of quantitative lithofacies palaeogeography", *i.e.*, the "4 steps mapping method", the nomenclature of each palaeogeographic unit in palaeogeographic map, the explanation of each palaeogeographic unit in palaeogeographic map, the explanation of significance of palaeogeographic map and palaeogeographic article, the evaluative standards of palaeogeographic map and palaeogeographic article, and the self-evaluation. Criticisms and corrections are welcome.


## 1. Introduction

The palaeogeographic map is a graphic representation of physical geographical characteristics in geological history periods and human history periods. It is the most important result of any palaeogeographic study.

Palaeogeography is a science that studies the characteristics and evolution of physical geography in geological history periods and human history periods (Feng, 2003, 2009; Feng and Bao, 2012; Feng *et al.*, 2012).

The geological history periods include all the geological history periods before the Quaternary.

The human history periods are the periods of humankind activity after the Quaternary. The Quaternary is a transitional period.

The characteristics of physical geography are the features and distribution of lands and seas and their subunits in lands and seas.

According to different aims and emphases, the palaeogeographic map can be divided into different types, such as the lithofacies palaeogeographic map or sedimentary palaeogeographic map, the biopalaeogeographic map, the tectonopalaeogeographic map, the qualitative palaeogeographic map, the quantitative palaeogeographic map, the palaeogeographic map of present boundary, the palaeogeographic map of non-present boundary, the palaeogeographic map of "fixism", the palaeogeographic map of "mobilism", the palaeogeographic map of different periods, the palaeogeographic map of different areas, the palaeogeographic map of different scales, *etc.*

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In recent years, in the articles published in or submitted to the *Journal of Palaeogeography* (Chinese Edition and English Edition), and in the relevant papers and books of others, problems have appeared. Some of them are serious.

These problems mainly include the data of palaeogeographic mapping, the methods of palaeogeographic mapping, the nomenclature and explanation of palaeogeographic units in palaeogeographic map, the explanation of significance of palaeogeographic map and palaeogeographic article and book, the evaluative standards of palaeogeographic map and palaeogeographic article and book, *etc.*

The author, as the Editor-in-Chief of the *Journal of Palaeogeography* (Chinese Edition and English Edition) aimed at these problems in the Journal and the relevant papers and books of others, and integrated with his practice of palaeogeographic study and mapping, wrote this paper. Criticisms and corrections will be heartily welcome.

## 2. Data of palaeogeographic mapping

The data is the first necessary for palaeogeographic mapping. It means that "mapping must be based on its data".

"Mapping must be based on its data" means that the determination and drawing of each palaeogeographic unit in a palaeogeographic map must be according to its data. This is the foothold of palaeogeographic maps and articles or books based on their palaeogeographic maps. This is the fundamental evaluative standard of palaeogeographic map and the articles or books based on their palaeogeographic maps.

### 2.1. *Reliability of data*

The data of palaeogeographic map mainly comes from outcrop sections and well sections.

The reliability of these data is differential. It can be divided into 3 orders.

The quantitative and qualitative data of the outcrop sections that were studied and measured by me and my research team are reliable. They are the data of first order outcrop sections.

The quantitative and qualitative data of outcrop sections that were reviewed and partially measured by us are basically reliable. They are the data of second order outcrop sections.

The data of outcrop sections that were studied and measured by other researchers, especially by the geological survey teams, and were collected by us, in which the lithological descriptions are very simple and with little quantitative data, only the thickness data are basically reliable. They are the data of third order outcrop sections and they only can be used as reference.

The data from well sections that we were reviewed by us via the original logging data. In addition, we studied the cores, cuttings and their thin sections under polarized microscope. All these quantitative and qualitative data are reliable. They are the data of first order well sections.

The data from well sections that we were not reviewed via the original logging data, in which only the thickness data are reliable, but the other data can be used as reference. They are the data of second order well sections.

The data from well sections that we were not reviewed but were collected by us, can only be used as reference. They are the data of third order well sections.

We regard the data of first order outcrop sections, first order well sections, second order outcrop sections, and second order well sections as the firsthand data, and the data of third order outcrop sections and third order well sections as the secondhand data.

The firsthand data are most important. The more firsthand data are used, the more reliability of palaeogeographic map is.

The secondhand data are also necessary, however, they have to be selected seriously and they only can be used as the supplement and reference for the firsthand data. The more secondhand data are used, the less reliability of palaeogeographic map is.

### 2.2. *Representation of data*

The representation of data means that the data points (section points) in the study area should be with a sufficient amount and distributed uniformly, *i.e.*, should be representative for the study area.

However, in some articles published in the *Journal of Palaeogeography* (*JoP*) or in some manuscripts submitted to *JoP*, the distribution of data points was without representation for the study area.

For example, in a manuscript of an article submitted to the *JoP*, in the isoline map of thickness of a stratigraphic unit of Iran, there were only 7 outcrop sections located in the southern part of Iran; but the article's authors had composed the isoline map of thickness of the stratigraphic unit in the whole area of Iran. Certainly, I don't believe this isoline map of thickness.

The proverb said: "**The cleverest housewife can't cook a meal without rice**". It contains 3 implications: ① The first is "rice", *i.e.*, the materials for "cook". ② The second is the "cleverest housewife", *i.e.*, the highly skilled cooking method. ③ The third is "meal", *i.e.*, the cooking outcomes or the delicacies.

In palaeogeographic mapping, it means that: ① The first is the data, especially the firsthand data, like the "rice". ② The second is the method or methodology, like the cooking craft of the "cleverest housewife". ③ The third is the palaeogeographic map, like the "meal".

In a word, about the palaeogeographic mapping, the data is the first necessary. If without the reliable and representative data, any distinguished geologist can't compose a palaeogeographic map.

## 3. Problems of palaeogeographic mapping method

As mentioned above, the first is the data (rice), the second is the method or methodology (cooking craft of the cleverest housewife). Therefore, after the reliable and representative data obtained by us, the method or methodology of palaeogeographic mapping is the key problem.

Mao (1934) said: "**If our task is to cross a river, we can't cross it without a bridge or a boat. Unless the bridge or boat problem is solved, it is idle to speak of crossing the river. Unless the problem of method is solved, talk about the task is useless**".

Our task is to compose the palaeogeographic map. Now, we have already obtained the reliable and representative data, we have to solve the problem of method or methodology of palaeogeographic mapping.

The following are the problems of palaeogeographic mapping method of the *Atlas of* Palaeogeography of China (1955) and the articles published in or submitted to the *Journal of Palaeogeography*.

### 3.1. *Problems of mapping method of the Atlas of Palaeogeography of China (1955)*

The *Atlas of Palaeogeography of China* by Prof. Liu (1955) is the formal starting point and the first milestone of palaeogeography in China.

The palaeogeographic maps in *Atlas of Palaeogeography of China* are the basical distribution maps of old lands and old seas. Therefore, how to define the old lands and old seas in geological history periods, is the key problem of this book.

The mapping method to define the old lands and old seas in the *Atlas of Palaeogeography of China* is that: **Where at present the stratum with marine fossils was an old sea when the stratum was formed, and where at present the stratum without marine fossils was an old land when the stratum was formed**.

Prof. Li Siguang, a distinguished geologist of China, in 1955 and in the preface of the *Atlas of Palaeogeography of China*, had already pointed out: the assumption "where at present the stratum without marine fossils was an old land when the stratum was formed" is not absolutely right.

However, in 1950s, I just took a teaching post in Beijing Institute of Petroleum and had not studied palaeogeography formally. I only read the *Atlas of Palaeogeography of China*, I considered it as a classical book, but I did not understand that the assumption "where at present the stratum without marine fossils was an old land when the stratum was formed" is not absolutely right.

In 1970s, I and my students of East China Institute of Petroleum studied and measured the outcrop sections of the Lower Paleozoic in central Shandong Province, which are mainly composed of marine carbonate rocks. When we were going to study and measure the outcrop sections of the Lower Paleozoic in Weifang area of eastern Shandong Province, I supposed that the Lower Paleozoic in Weifang area must be with more clastic rocks and may be with coarse sandstones and conglomerates, because the Weifang area is adjacent to the so-called "Jiaoliao Old Land" defined by Prof. Liu Hongyun in the *Atlas of Palaeogeography of China*. However, during the study and measurement of the outcrop sections of the Lower Paleozoic in Weifang area, I found that the rock types and the thickness of stratigraphy of the Lower Paleozoic in Weifang area are basically similar to those in central Shandong Province, and I never found more clastic rocks, not to mention the coarse sandstones and conglomerates. I was surprised at those. Therefore, a question in my mind was originated: "Where was the Jiaoliao Old Land"?

In the next years, when we studied and measured the outcrop sections of the Lower Paleozoic in Beijing area, I had the same question about the so-called "Inner Mongolia Old Land" in the *Atlas of Palaeogeography of China*: "Where was the Inner Mongolia Old Land"?

For this reason, in my first article of palaeogeographic study *A preliminary discussion on the Early Ordovician Lithofacies and palaeogeography in North China* (Feng, 1977, 1979), I pointed out my idea that the Jiaoliao Old Land and Inner Mongolia Old Land might not have existed in the Early Ordovician. However, in the palaeogeographic maps of my article, I did not dare to delete the two old lands, and they were drawn with dotted lines. It is difficult for me, a young geologist, to define whether the two old lands existed or not.

In 1980s, we went to Shanxi Province and even went to the Wutai Mountains to study and measure the outcrop section of the Lower Paleozoic. It is a powerful negation of the existence of the so-called Wutai Old Land of the Lower Paleozoic in the *Atlas of Palaeogeography of China*.

Therefore, the assumption "where at present the stratum without marine fossils was an old land when the stratum was formed" is really with problems: ① Where at present the stratum without marine fossils might be that the stratum with marine fossils formed in a certain geological period but was eroded away in the later geological period when this area was uplifted and suffered from erosion. The Jiaoliao Old Land and Inner Mongolia Old Land may be in this case. ② Where at present the stratum without marine fossils might be resulted from the deficiency of geological work. The Wutai Old Land is in this case.

In a word, we have to understand that the palaeogeographic mapping method is very important. If the mapping method is with problems, the palaeogeographic map will also be with problems.

However, the problem of the mapping method of the *Atlas of Palaeogeography of China* was resulted from the academic level and historical conditions of geology of China in 1950s. Although Prof. Li Siguang had pointed out the problem in the preface of the *Atlas of Palaeogeography of China* and Prof. Liu Hongyun should understand it, but he still used his original mapping method. This is the history!

We cannot evaluate the *Atlas of Palaeogeography of China* published in 1950s with the present standards. Although the *Atlas of Palaeogeography of China* was with problems in its mapping method, it does not affect the academic position of this book in China, *i.e.*, the formal starting point and the first milestone of palaeogeography in China.

It is that one flaw cannot obscure the splendor of the jade.

Similar problems existed in other palaeogeographic books and articles in China.

### 3.2. *About the preparatory maps — problems of mapping method in other articles*

In recent years, in some articles published in *Journal of Palaeogeography* (JoP) or submitted to it, some authors composed some maps, such as the isopach map or the isoline map of thickness, the correlation map of stratigraphy, the

correlation map of sedimentary facies, the isoline map of thickness of sandstone, the isoline map of content (%) of sandstone, the isoline map of the ratio of sandstone thickness to stratum thickness, the isoline map of the ratio of sandstone to mudstone, *etc.*, as the preparatory maps for palaeogeographic mapping. This is a good method for palaeogeographic mapping. However, there are problems in these preparatory maps.

#### 3.2.1. *About the isopach map*

The isopach map or the isoline map of thickness of a stratigraphic unit in a study area is a very useful preparatory map for palaeogeographic mapping.

In order to compose a qualified isopach map, we should pay attention to the following 3 points.

① We have to get the sufficient, uniformly distributed and reliable data of thickness of the stratigraphic unit in a study area.

The "sufficient and uniformly distributed" is a relative statement. It means that the data points (section points) have to be with the representation of the stratigraphic unit in a study area.

The "reliable" means that the data should be mainly the firsthand data, and the secondhand data have to be selected rigorously.

It is the precondition for the mapping of an isopach map.

② The drawing of thickness isoline should be within a stratigraphic area. About the trans-area drawing, it should be more careful.

③ Generally speaking, the isoline map of thickness of a stratigraphic unit in a study area has to have distributional regularity. If the distribution of the isoline map of thickness of a stratigraphic unit in a study area is disordered, the isoline map may be with problems.

For example, in an article (Li and He, 2014) published in the *JoP* (Chinese Edition), the section points of the isoline maps of thickness were only located in the cross profile lines and thus did not represent the whole study area. In addition, the authors did not state the orders of these section data. Some isolines were broken lines and some isolines ran towards the old land. In a word, these isoline maps were without regularity.

What is the use of isopach map?

An isopach map mainly reflects the distribution of the stratigraphic unit in a study area and its palaeotectonic framework of the geological period.

Generally speaking, an area with a large thickness mainly reflects that the depression range of the area might be large; an area with a small thickness mainly reflects that the depression range of the area might be small; an area with the thickness "zero" mainly reflects that the area was an uplift area or an old land in the geological period.

The thickness of a stratigraphic unit of an area does not reflect its water depth. An area with a large thickness may not be with deep water, an area with a small thickness may not be with shallow water, and an area with the thickness "zero" may not be an old land. For example, a starved basin may be always with a small thickness, but it is always with deep water. A carbonate platform or clastic platform may be always with a large thickness, but it is always with shallow water. As for whether an area with the thickness "zero" is an old land or not, it is required to identify whether the "zero" is a "sedimentary zero" or an "eroded zero". Additionally, it is also necessary for some evidence of the marginal facies adjacent to the old land. Therefore, the explanation of isopach map is most important and should be with care and caution.

#### 3.2.2. *About the correlation map of stratigraphy*

Some authors (Li and He, 2014) composed a correlation map of the stratigraphic unit in a study area, as a preparatory map for the palaeogeographic mapping.

The correlation map of the stratigraphic unit can distinctly represent the thickness and lithologic characters (if there are lithologic characters in the map) of the stratigraphic column sections in a study area.

However, for the palaeogeographic mapping, the use of the correlation map of stratigraphy is less than that of the isopach map.

#### 3.2.3. *About the correlation map of sedimentary facies*

Some authors (Mou *et al.*, 2014) composed a correlation map of sedimentary facies of the stratigraphic units in a study area, as a preparatory map for the palaeogeographic mapping.

The correlation map of sedimentary facies can distinctly represent the characters and changes of sedimentary facies of the stratigraphic column sections in a study area.

However, for the palaeogeographic mapping, the use of the correlation map of sedimentary facies is less than that of the distribution map of sedimentary facies of all sections in a study area, or the division map of sedimentary facies in a study area.

#### 3.2.4. *About the isoline map of thickness of sandstone, the isoline map of content (%) of sandstone, the isoline map of the ratio of sandstone thickness to stratum thickness, the isoline map of the ratio of sandstone thickness to mudstone thickness etc*

In the articles of palaeogeographic study of clastic rocks, some authors (Shao *et al.*, 2015) composed the isoline map of thickness of sandstone, the isoline map of content (%) of sandstone, the isoline map of the ratio of sandstone thickness to stratum thickness, the isoline map of the ratio of sandstone thickness to mudstone thickness, *etc.*, in a study area, as the preparatory maps for the palaeogeographic mapping.

These preparatory maps can distinctly represent the richness of sandstone of the stratigraphic units in a study area, and are useful for the reconstruction of sedimentary facies of the study area. However, only according to these preparatory maps regarding the richness of sandstone, it is impossible to compose a qualified palaeogeographic map.

#### 3.2.5. *Interim summary*

In a word, all the above preparatory maps in 3.2.1–3.2.4, are useful for palaeogeographic mapping. However, only according to the preparatory maps, it is impossible to compose a qualified palaeogeographic map.

Why is it impossible?

Because the above authors may not understand the aim of composing these preparatory maps, *i.e.*, they may not understand how to utilize these preparatory maps to determine palaeogeographic units. It is more important that the above authors have no an effective methodology that governs the palaeogeographic mapping as a whole.

The following is the methodology of palaeogeographic mapping of the author.

## 4. Methodology of the author

In palaeogeographic study and palaeogeographic mapping, the author initiated and utilized the "Single factor analysis and multifactor comprehensive mapping method — Methodology of quantitative lithofacies palaeogeography" (Feng, 1977, 1979, 1987, 1989, 1992, 1994, 2004; Feng *et al.*, 2001, 2004, 2014).

It is a methodology that governs the palaeogeographic mapping as a whole.

On the basis of reliable and representative data of sections of the stratigraphic unit in a study area, we firstly composed some preparatory maps, mainly isoline maps of single factors, in which we can define some palaeogeographic units of different orders; then superposed all the preparatory maps, through overall examination, comprehensive judgement, discarding the dross and selecting the essential, discarding the false and retaining the true; and finally compose the qualified palaeogeographic maps step by step.

In this article, we utilize some case studies, to explain how to use the methodology and the preparatory maps to compose the qualified palaeogeographic maps step by step.

### 4.1. *To define old land and old sea*

The old land and old sea are the first order palaeogeographic units.

In palaeogeographic mapping, to define the old land is the most important task. If the old land has been defined in a palaeogeographic map, the rest area can be defined as the old sea.

#### 4.1.1. *To define old land only with eroded area*

On the basis of the isoline map of thickness and combined with the marine clastic marginal facies, we can define the old land only with eroded area.

According to the thickness (m) data of 157 sections (46 first order outcrop sections, 57 second order outcrop sections, 50 third order outcrop sections, 3 first order well sections, 1 second order well section), the isoline map of thickness (m) of the Early Age of Early Ordovician in South China was composed (Fig. 1).

In Fig. 1, the "thickness zero" area (brown color area) was a "sedimentary zero" area. Combined with the coarse clastic rocks, *i.e.*, the marine clastic marginal facies in its peripheral area (Feng *et al.*, 2001, 2014), we can define the "sedimentary zero" area as an old land only with eroded area, *i.e.*, the Kangdian Land, and the rest area as the old sea.

For another example, according to the thickness (m) data of 38 sections (9 first order outcrop sections, 4 second order outcrop sections, 2 third order outcrop sections, 20 first order well sections, 2 second order well sections, 1 third order well section), the isoline map of thickness (m) of the Early Ordovician Majiagou Age 1 of Ordos in North China was composed (Fig. 2).

In Fig. 2, the "thickness zero" area (brown color area) was a "sedimentary zero" area. Combined with the penecontemporaneous dolostone, *i.e.*, the marine carbonate marginal facies in its peripheral area (Feng *et al.*, 1998a, 2014), we can define the "sedimentary zero" area as an old land only with eroded area, *i.e.*, the Ordos Land, and the rest area as the old sea.

In Fig. 1, the old land was defined by the "thickness zero" area and its surrounding marine coarse clastic marginal facies. In Fig. 2, the old land was defined by the "thickness zero" area and its surrounding marine carbonate (penecontemporaneous dolostone) marginal facies.

In addition, there was another case, *i.e.*, the old land was surrounded by the marine mudstone marginal facies. The North China Land in the Early Cambrian Mantou Age and the Middle Cambrian Maozhuang Age in North China was surrounded with a large area of marine mudstone (Feng *et al.*, 1990, 2004).

All of these are that the old land was only with eroded area and its surrounding rocks were marine facies.

About how to define the old land both with eroded area and terrestrial sediment area, please see the following.

#### 4.1.2. *To define old land both with eroded area and terrestrial sediment area*

In order to define the old land both with eroded area and terrestrial sediment area, it is in need of other preparatory maps, such as the isoline map of content (%) of marine rocks, *etc.*

According to the thickness (m) data of 96 sections (15 first order outcrop sections, 16 second order outcrop sections, 45 third order outcrop sections, 9 first order well sections, 11 second order well sections), the isoline map of thickness (m) of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China was composed (Fig. 3).

In Fig. 3, the "thickness zero" area (brown color area) was an eroded area of the old land. In its peripheral area, there were terrestrial sediments.

According to the content (%) data of the marine rocks of 75 sections (13 first order outcrop sections, 23 second order outcrop sections, 23 third order outcrop sections, 15 first order well sections, 1 second order well section), the isoline map of content (%) of the marine rocks of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China was composed (Fig. 4).

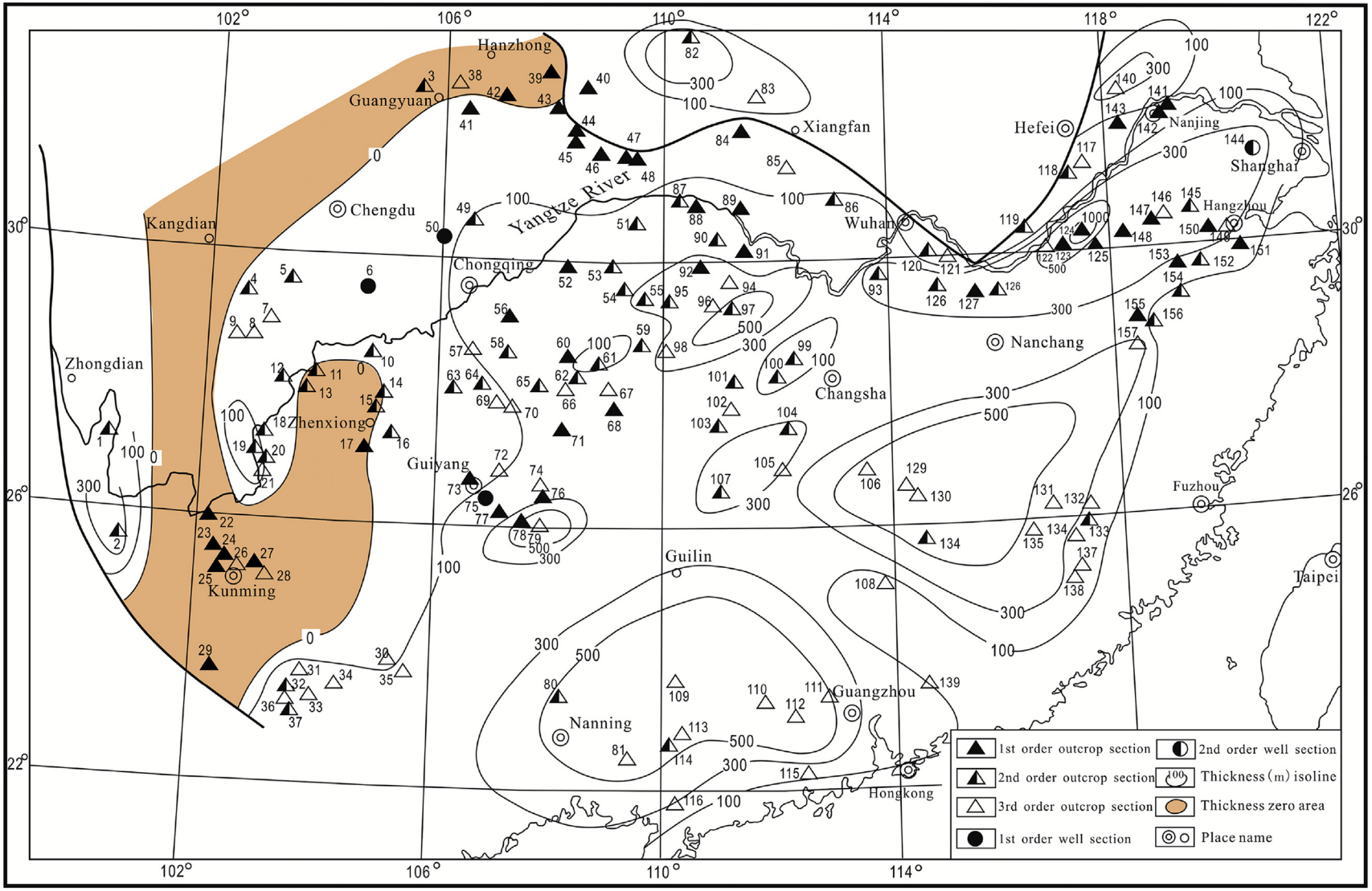


**Fig. 1 – Isoline map of thickness (m) of the Early Age of Early Ordovician in South China (modified from Feng *et al.*, 2014).**

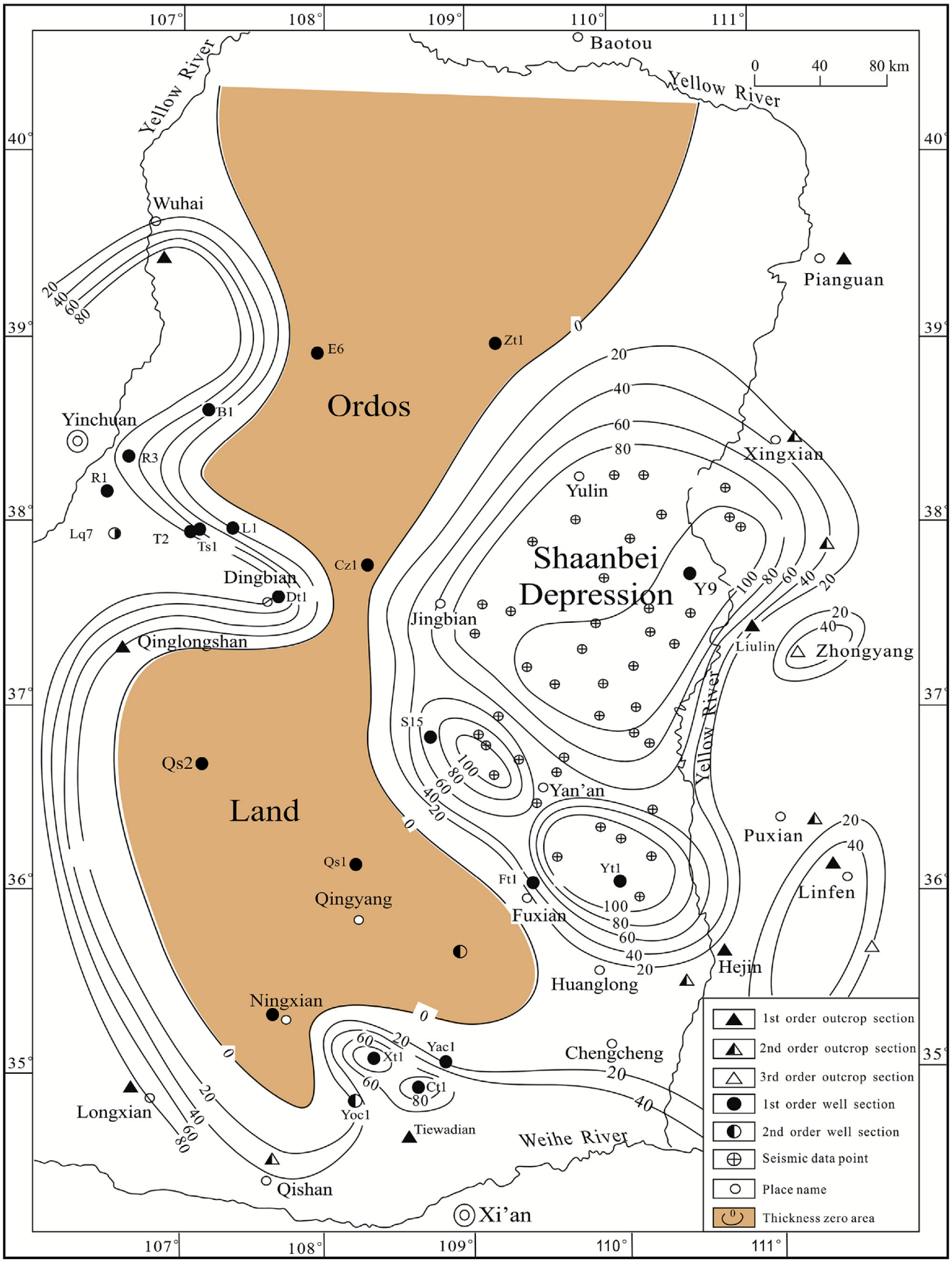


**Fig. 2 – Isoline map of thickness (m) of the Early Ordovician Majiagou Age 1 of Ordos in North China (modified from Feng *et al.*, 2014).**

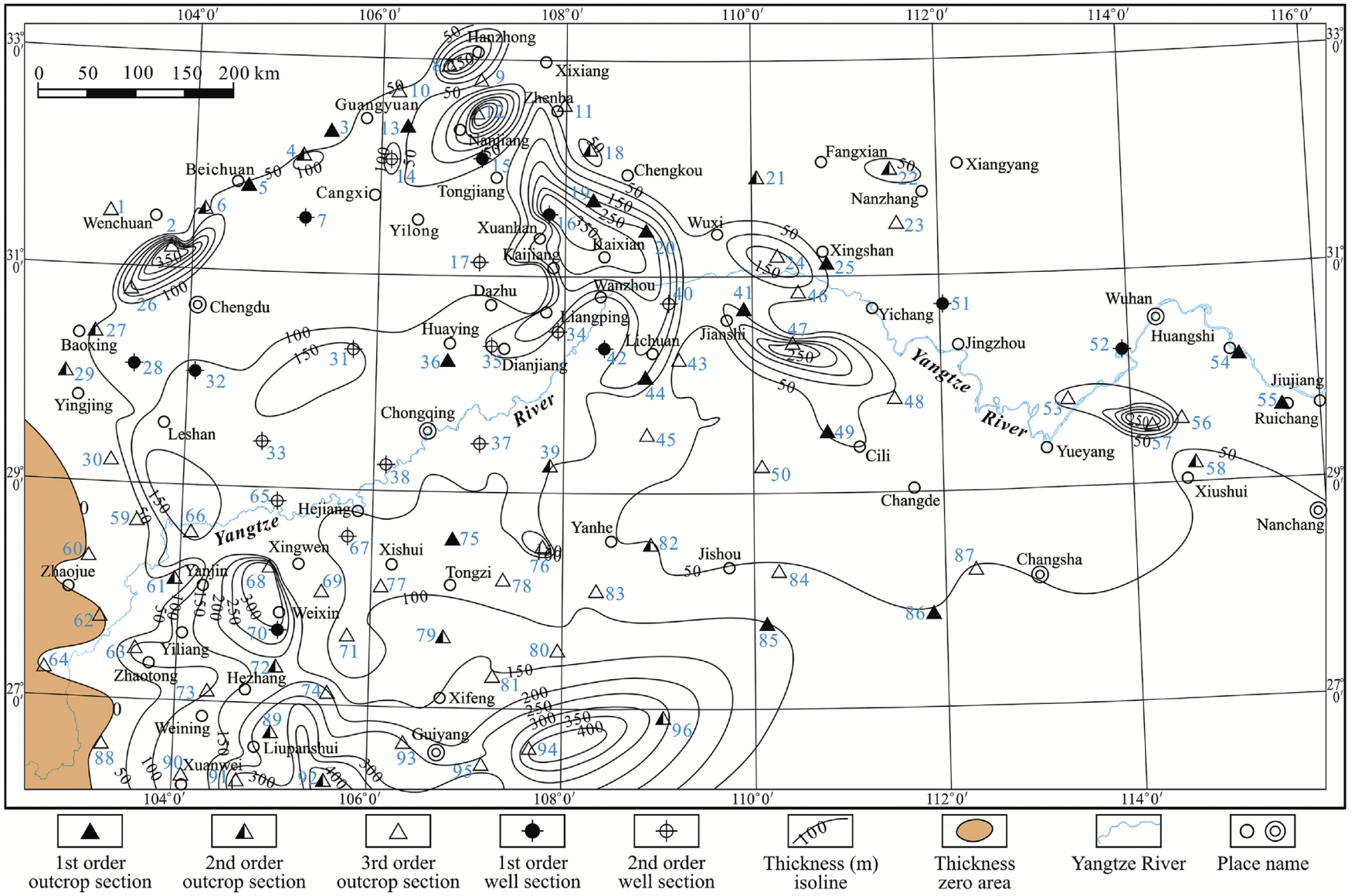


**Fig. 3 – Isoline map of thickness (m) of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region (modified from Luo *et al.*, 2014).**

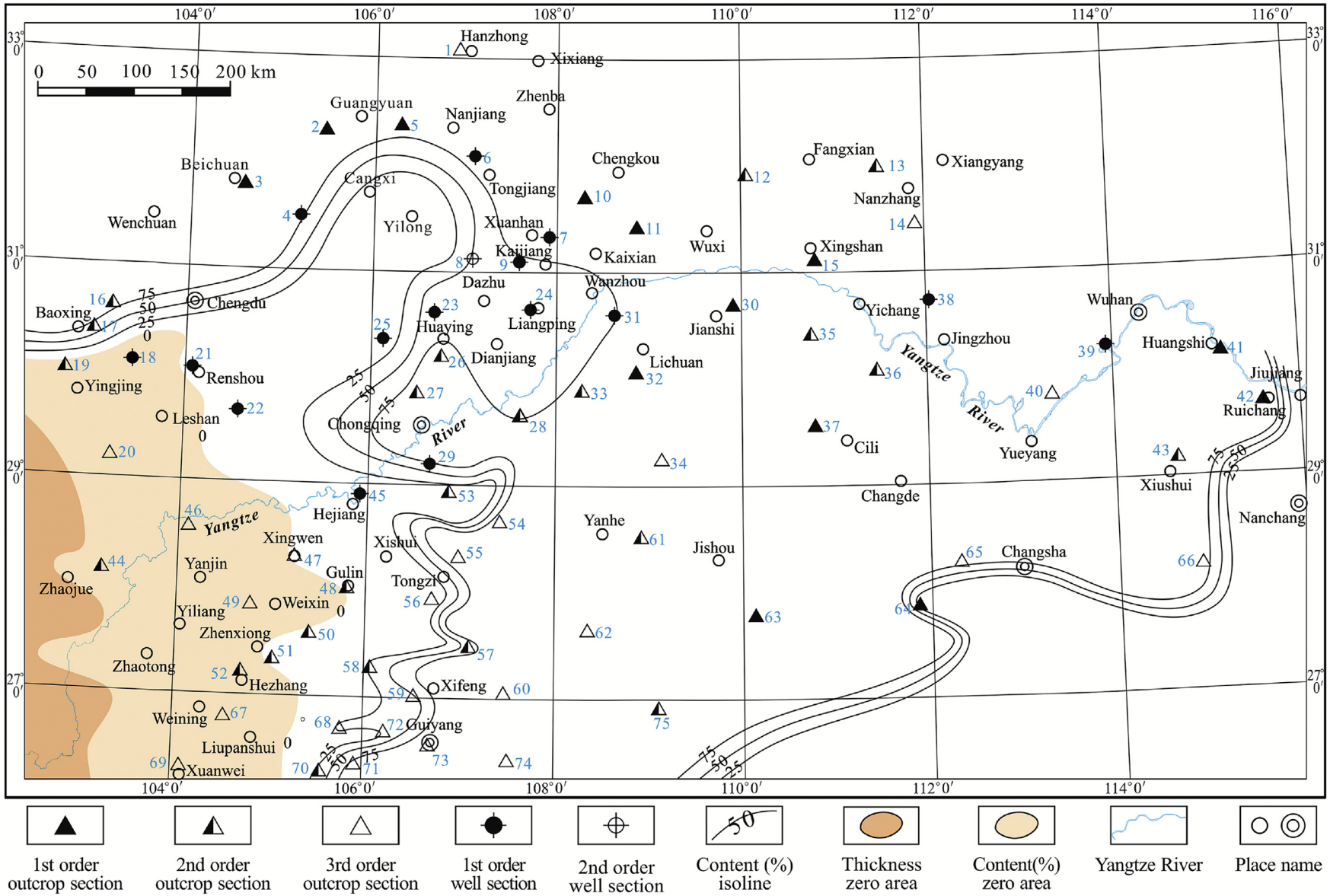


**Fig. 4 – Isoline map of content (%) of the marine rocks and the old land both with eroded area (brown area) and terrestrial sedimentary area (light brown area) of the Late Permian Wujiaping Age of Middle and Upper Yangtze Region in South China (modified from Luo *et al.*, 2014).**

In Fig. 4, the "content zero" area of marine rocks (brown area and light brown area) included both the eroded area and terrestrial sediment area.

The area between the "content zero" line of marine rocks (in Fig. 4) and "thickness zero" line (in Fig. 3) was the "terrestrial sediment area" (light brown area).

The "content zero" line of marine rocks (in Fig. 4) was the boundary between the old land (both with eroded area and terrestrial sediment area) and the old sea.

In fact, the boundary between the old land (both with eroded area and terrestrial area) and old sea in geological time was a transitional belt between the marine sediment area and terrestrial sediment area. The line between the old land (both with eroded area and terrestrial area) and old sea in palaeogeographic map was an average line of the transitional belt.

Sometimes, we can firstly compose the isoline map of content (%) of terrestrial rocks, and then utilize the "content zero" line of terrestrial rocks as the boundary between the old land (both with eroded area and terrestrial area) and the old sea. It is determined by the concrete conditions of the stratigraphy unit in a study area.

Up to now, we can define the old land (only with eroded area and both with eroded area and terrestrial area) and the old sea in the palaeogeographic map. It means that we can compose the distribution map of old lands and old seas, *i.e.*, the most fundamental palaeogeographic map.

This is the first step of palaeogeographic mapping.

### 4.2. *To define basin and platform in old sea*

#### 4.2.1. *To define basin*

According to the content (%) data of deep water rocks (thin-bedded siliceous rock, siliceous shall, dark medium-bedded to thin-bedded micritic limestone, dark mudstone, *etc.*) of 71 sections (14 first order outcrop sections, 28 second order outcrop sections, 19 third order outcrop sections, 10 first order well sections), the isoline map of content (%) of these deep water rocks of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China was composed (Fig. 5).

In Fig. 5, we can define the area of content of deep water rocks $\geq$50% as the deep water sedimentary area (blue color area), *i.e.*, the deep water basin (basin) in the old sea, and the rest area as shallow water sedimentary area, *i.e.*, the shallow water platform (platform) in the old sea.

#### 4.2.2. *To define shale basin*

Sometimes, on the basis of the content (%) data of a certain deep water rock, such as deep water shale, or deep water limestone, or deep water siliceous rock, or deep water gravity flow sediment, or deep water flysch sediment, *etc.*, we can firstly compose the isoline map of content (%) of a certain deep water rock of the stratigraphic unit in a study area, and then define the area of content of a certain deep water rock $\geq$50% as a certain deep water basin.

For example, according to the content (%) data of deep water shale of 57 sections (12 first order outcrop sections, 23 second order outcrop sections, 22 third order outcrop sections), the isoline map of content (%) of deep water shale of the Early Age of Early Ordovician in South China was composed (Fig. 6).

In Fig. 6, we can define the areas of content (%) of deep water shale $\geq$50% as deep water shale basins (shale basins) (blue color areas) in old sea. There were a large shale basin (Jiangnan Shale Basin) and 11 small shale basins (Fig. 6).

Owing to that the deep water rocks in the lower part of Lower Ordovician in South China were mainly deep water shales, we can define the rest area of the study area as shallow water sedimentary area, *i.e.*, the platform in the old sea.

#### 4.2.3. *Basin and trough*

In a palaeogeographic map, there are two types of deep water sedimentary area, one is the deep water sedimentary area in the plate, and the other is the deep water sedimentary area outside the plate or between plates.

The deep water sedimentary area in the plate is called deep water basin or basin. It was mentioned above.

The deep water sedimentary area outside the plate or between plates is called deep water trough or trough, because its shape is always elongated. The trough resulted from the collision and combination of two plates, and therefore its area between them was consumed greatly. Prof. Wang Hongzhen called it as "crustal consumption zone" (Wang, 1985). In fact, it is better to call it as "palaeo-sea consumption zone" or "palaeo-ocean consumption zone". For examples, The Tianshan–Beishan–Mengliaoji Trough, Kunlun Trough and Qiling Trough in palaeogeographic maps in *Lithofacies Palaeogeography of the Cambrian and Ordovician in China* (Feng *et al.*, 2004) were deep water sedimentary areas outside plates or between plates, *i.e.*, the "palaeo-ocean consumption zones". The Jiangnan Basin in palaeogeographic map of this book might be also a trough (Wu, 2005).

The characteristics of basin and trough are obviously different from each other. In general, the water depth in trough was always deeper than that in basin.

#### 4.2.4. *To define carbonate platform and clastic platform*

After the deep water sedimentary area (basin and trough) and shallow water sedimentary area (platform) have been defined, and in the platform, on the basis of the isoline map of content (%) of shallow water carbonate rocks, we can define the area of content of carbonate rocks $\geq$50% as carbonate platform, and the rest area as the clastic platform in the old sea.

According to the content (%) data of shallow water carbonate rocks of 80 sections (19 first order outcrop sections, 20 second order outcrop sections, 37 third order outcrop sections, 3 first order well sections, 1 second order well section), the isoline map of content (%) of shallow water carbonate rocks of the Early Age of Early Ordovician in South China was composed (Fig. 7).

In Fig. 7, we can define the area of content of shallow water carbonate rocks $\geq$50% as the shallow water carbonate platform (light blue color area) in the old sea, *i.e.*, the Yangtze Carbonate Platform (Fig. 7).

In Fig. 7, the content (%) of shallow water carbonate rocks and the content (%) of shallow water clastic rocks have an

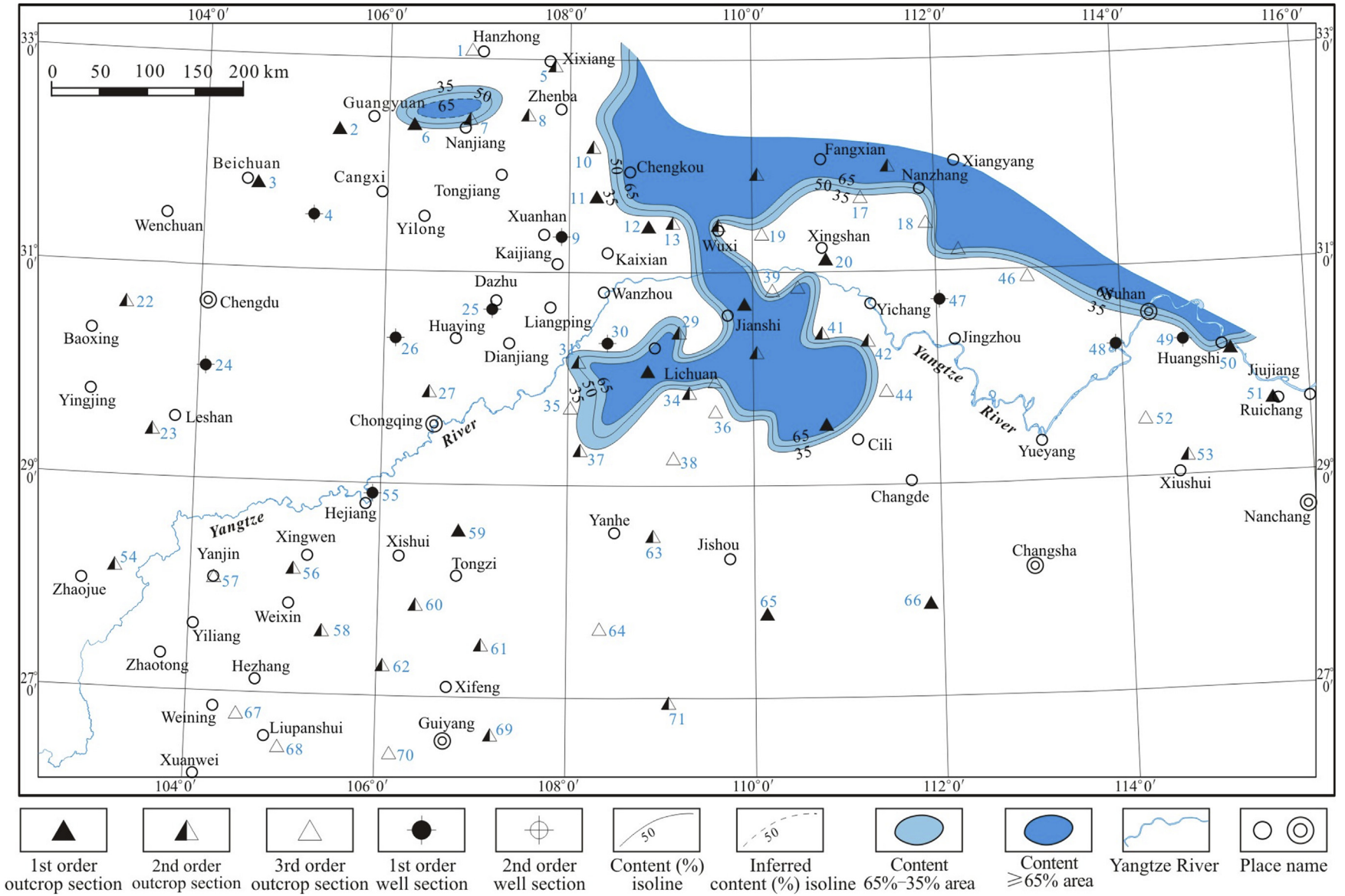


**Fig. 5 – Isoline map of content (%) of deep water rocks and the deep water basin of the Late Permian Wujiaping Age of Middle and Upper Yangtze Region in South China (modified from Luo *et al.*, 2014).**

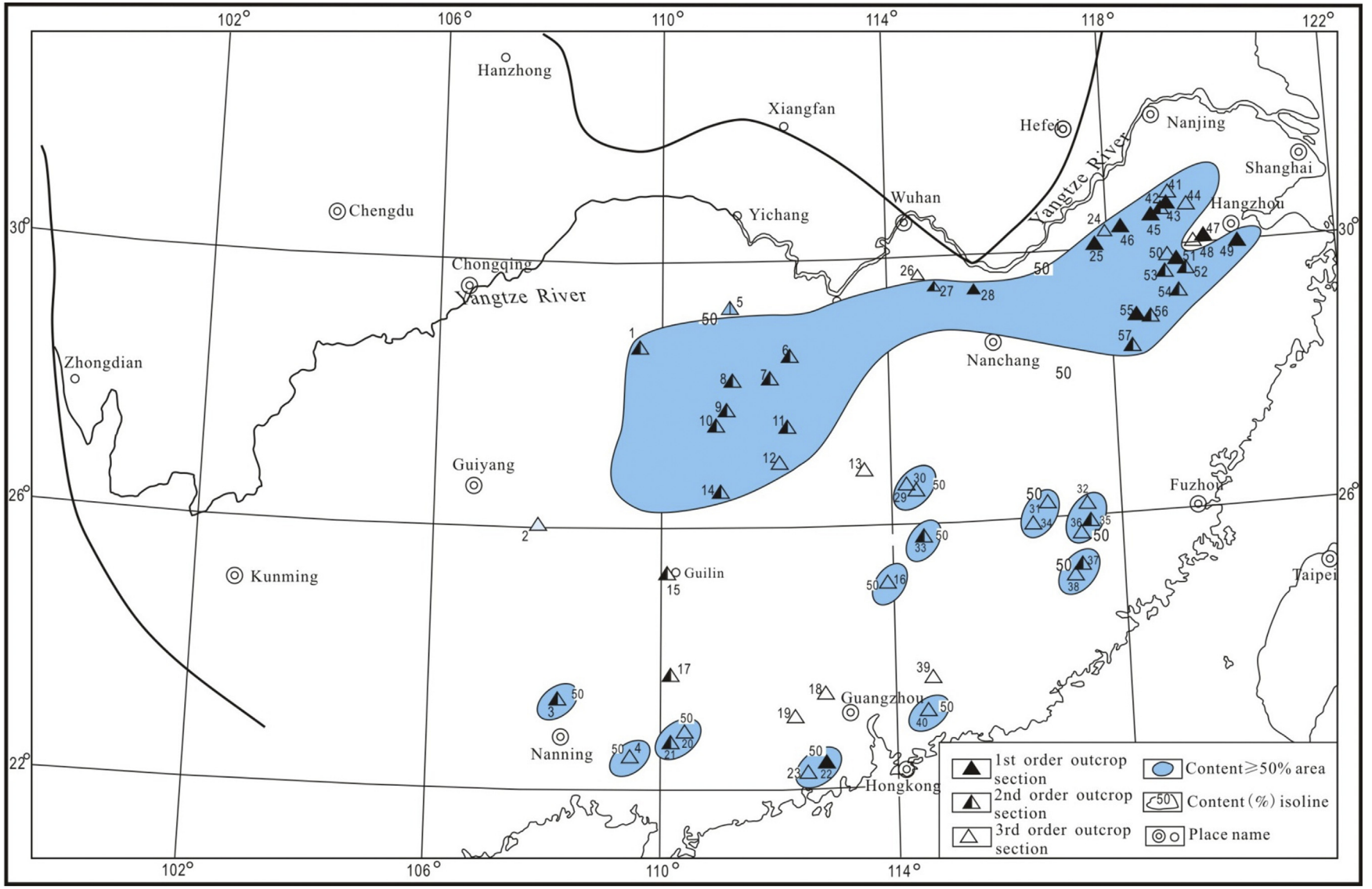


**Fig. 6 – Isoline map of content (%) of deep water shale and shale basins of the Early Age of Early Ordovician in South China (modified from Feng *et al.*, 2014).**

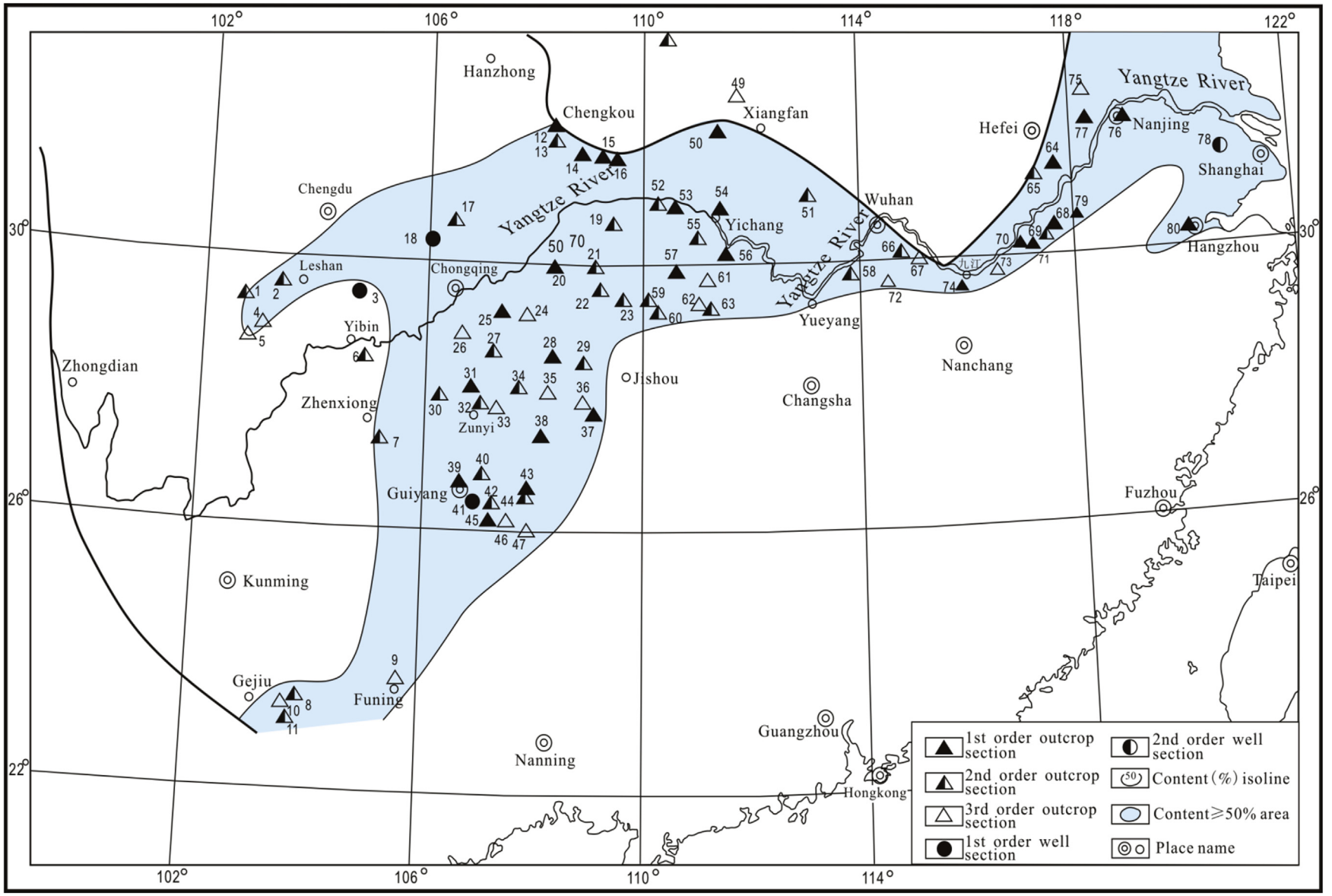


**Fig. 7 – Isoline map of content (%) of shallow water carbonate rocks and Yangtze Carbonate Platform of the Early Age of Early Ordovician in South China (modified from Feng *et al.*, 2014).**

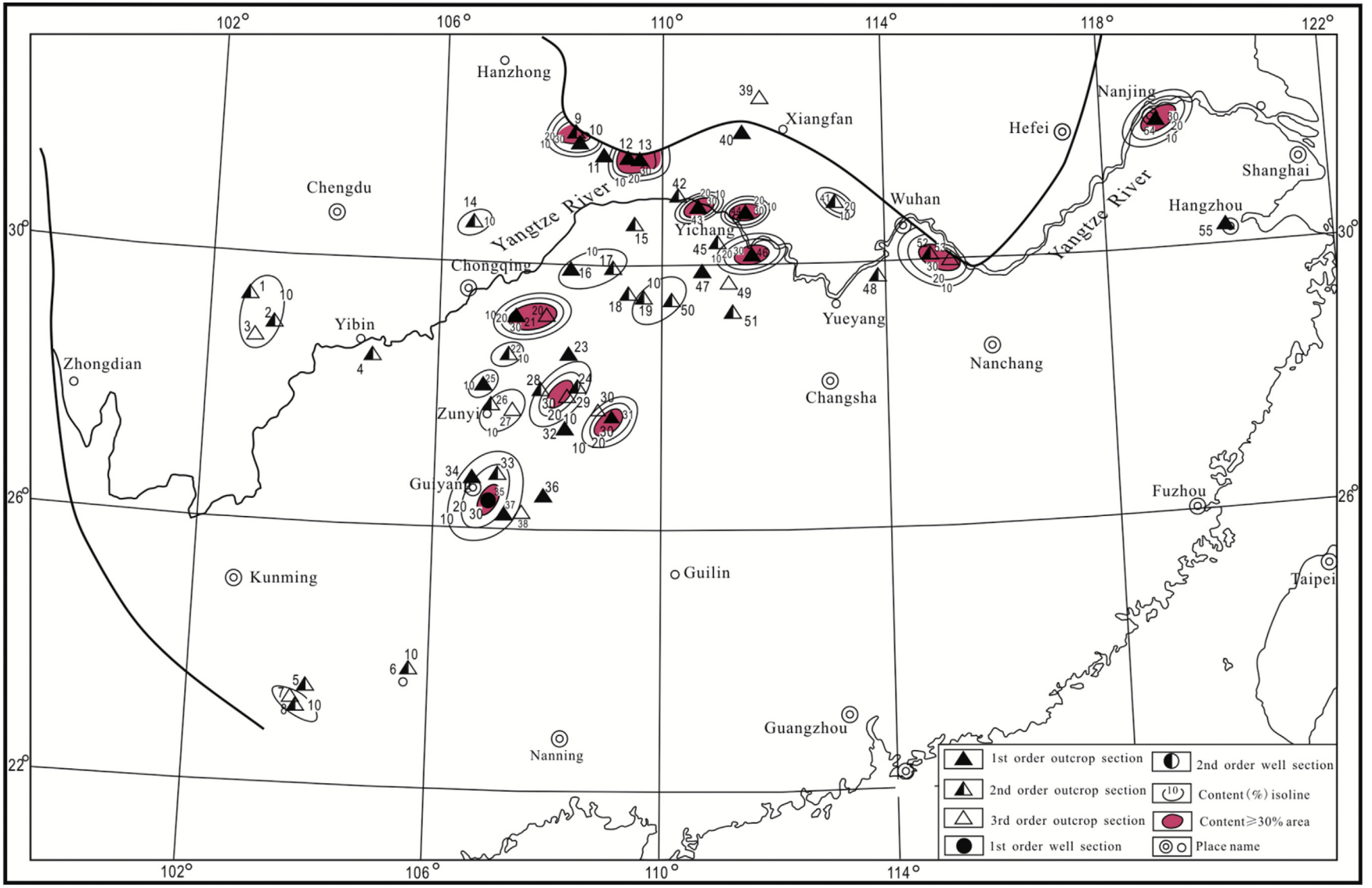


**Fig. 8 – Isoline map of content (%) of the grains with sparry calcite cement and sparry banks in carbonate platform of the Early Age of Early Ordovician in South China (modified from Feng *et al.*, 2014).**

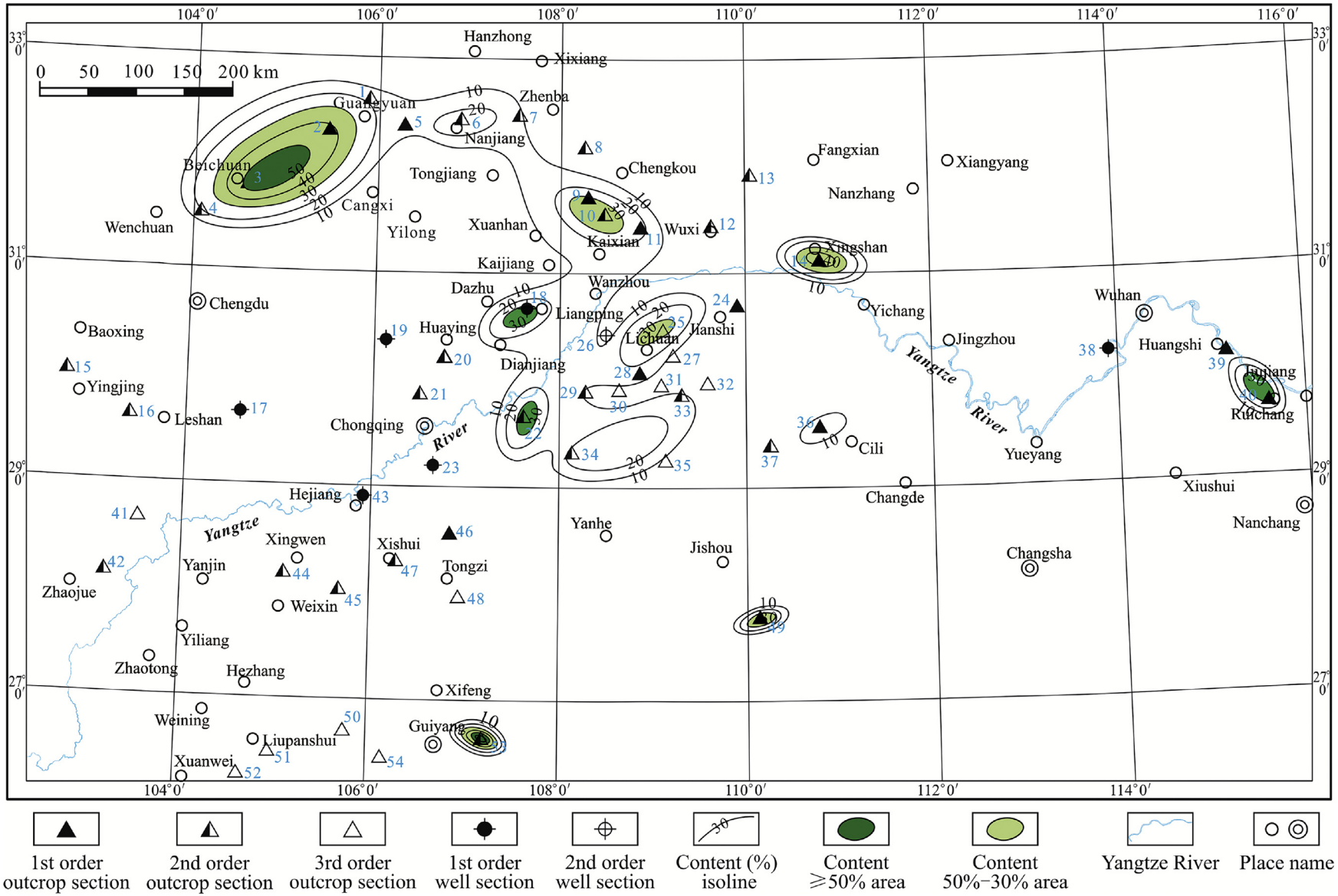


**Fig. 9 — Isoline map of content (%) of biograins *in situ* and biocrowd and penebiocrowds in carbonate platform of the Late Permian Wujiaping Age of Middle and Upper Yangtze Region in South China (modified from Luo *et al.*, 2014).**

inverse relationship, therefore, the area with shallow water carbonate rocks content <50% (*i.e.*, the shallow water clastic rocks content ≥50%), can be defined as clastic rock platform, *i.e.*, the Southeast Clastic Rock Platform and Chuan-xi–Diandong Clastic Rock Platform (see Fig. 11).

Sometimes, we can firstly compose the isoline map of content (%) of shallow water clastic rocks and define the clastic platform, and then define the rest area as the carbonate platform. It is determined by the concrete conditions of the stratigraphic unit in a study area.

In a word, on the basis of the isoline map of content (%) of deep water rocks, of a certain deep water rock (*e.g.*, shale), of shallow water carbonate rocks and of shallow water clastic rocks, we can define the different basins and different platforms in the old sea.

It means that, up to now, we can not only define the first order palaeogeographic units (old land and old sea), but also can define the second order palaeogeographic units (platform, basin, and trough) in the old sea.

This is the second step of palaeogeographic mapping.

### 4.3. *To define bank, biocrowd, flat, lake and reef in platform*

In platform, especially in carbonate platform, there are bank, biocrowd, flat, lake and reef. They are the third order palaeogeographic units.

#### 4.3.1. *To define bank*

In carbonate platform, the bank is a common and important palaeogeographic unit.

1) What is bank?

In 1988, in the book *Study of Lithofacies Palaeogeography of Qinglong Group of Lower–Middle Triassic in the Lower Yangtze River Region* (Feng *et al.*, 1988), the authors defined the areas with shallow water grains ≥30%, 29%–20%, 19%–10%, as bank, penebank and embryonic bank. The grains in carbonate rocks are mainly ooids, and with a small amount of sand-sized intraclasts and fossil fragments. The bank is an underwater high place which is located above the wave base and with high hydrodynamic energy. The penebank is also an underwater high place which is also located above the wave base and with high hydrodynamic energy but slightly less than that of bank. The embryonic bank is an embryonic state of bank that has the tendency to develop a penebank and bank. This is the first definition of bank, penebank and embryonic bank of quantitative lithofacies palaeogeography initiated by the authors. It is a development of the definition of bank. This definition of bank, penebank and embryonic bank was utilized by the authors in their articles and books during 1988–1998.

In 1998, in the book *Stratigraphy Petrology Lithofacies Palaeogeography of Ordovician is Ordos* (Feng *et al.*, 1998a) and *Lithofacies Palaeogeography of Carboniferous in South China* (Feng *et al.*, 1998b), the authors divided the shallow water grains into two types, *i.e.*, the grains with sparry calcite cement and the grains with limemud matrix, and then divided the bank into two types and six subtypes. The authors defined the areas of gains with sparry calcite cement ≥30%, 29%–20%, 19%–10% as sparry bank, sparry penebank and sparry embryonic bank; and defined the areas of grains with limemud matrix ≥30%, 29%–20%, 19%–10% as limemud bank, limemud penebank and limemud embryonic bank. It is a further development of the definition of banks. The definition of banks (two types and six subtypes) was utilized by the authors until today.

2) To define sparry bank

According to the content (%) of grains (ooids, sand-sized intraclasts, eroded fossil fragments) with sparry calcite cement in shallow water carbonate rocks of 55 sections (4 first order outcrop sections, 19 second order outcrop sections, 31 third order outcrop sections, 1 first order well section), the isoline map of content (%) of these grains with calcite sparry cement in carbonate platform of the Early Age of Early Ordovician in South China was composed (Fig. 8).

From Fig. 8, it can be seen:

① There are 14 sections in which the grains content is ≥30%. We can define these areas (red color areas) as sparry banks.
② There are 4 sections in which the grains content is 29%–20%. We can define these areas as sparry penebanks.
③ There are 21 sections in which the grains content is 19%–10%. We can define these areas as sparry embryonic banks.

The sparry banks, penebanks and embryonic banks, especially the sparry banks, are the typical banks which are formed and sedimented in the water body of high hydrodynamic energy.

In the Middle Cambrian Zhangxia Age and in the North China Platform, the typical oolitic banks were extraordinarily developed (Feng *et al.*, 1990, 2004).

3) To define limemud bank

However, if the grains are not with sparry calcite cement, but with limemud matrix, we can define the areas of content of these grains with limemud matrix ≥30%, 29%–20%, and 19%–10%, as limemud bank, limemud penebank and limemud embryonic bank.

The grains (ooids, sand-sized intraclasts, eroded fossil fragments) with limemud matrix are formed in the water body of high hydrodynamic energy, but are sedimented in the water body of low hydrodynamic energy. Therefore, these grains are coexisted with limemud.

The hydrodynamic conditions of water body of the limemud bank, penebank and embryonic bank are obviously different from that of sparry bank, penebank and embryonic bank.

The banks of the Early Ordovician Majiagou Age 1, 2, 3, 4, 5 of Ordos in North China were mainly limemud banks (Feng *et al.*, 1998a).

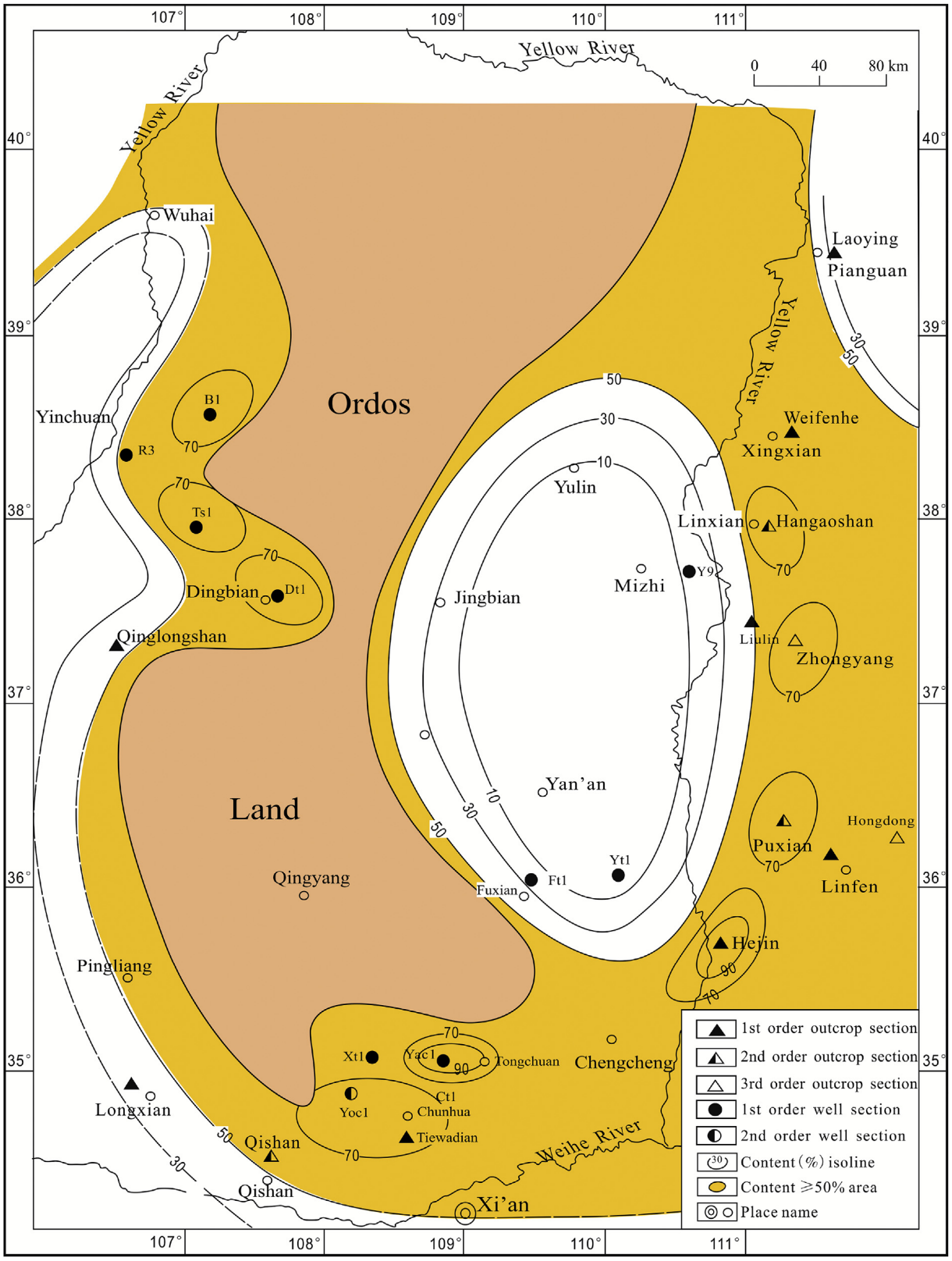


**Fig. 10 – Isoline map of content (%) of penecontemporaneous dolostone and dolostone flat of the Early Ordovician Majiagou Age 1 of Ordos in North China (modified from Feng *et al.*, 2014).**

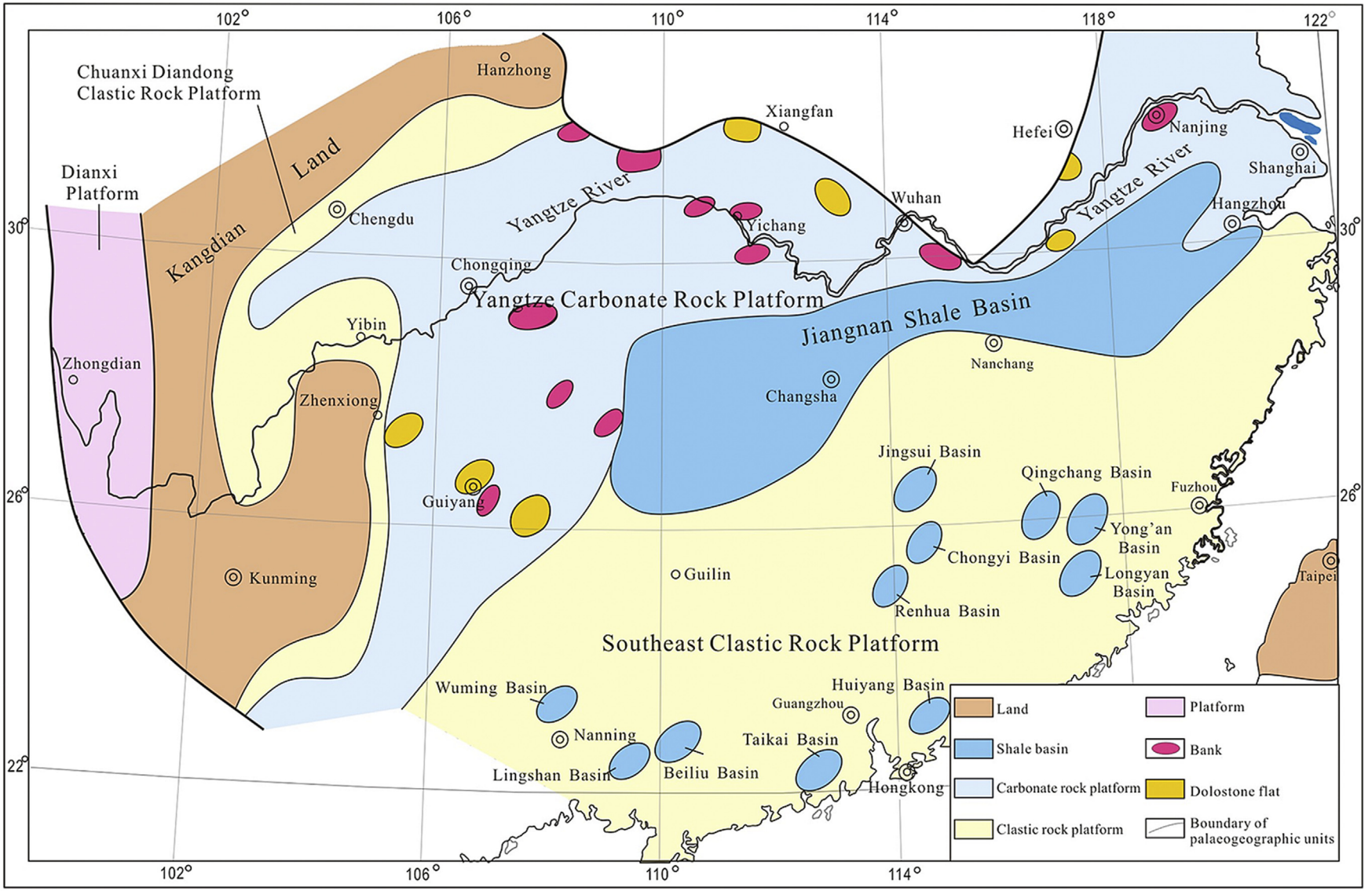


**Fig. 11 – Palaeogeographic map of the Early Age of Early Ordovician in South China (modified from Feng *et al.*, 2014).**

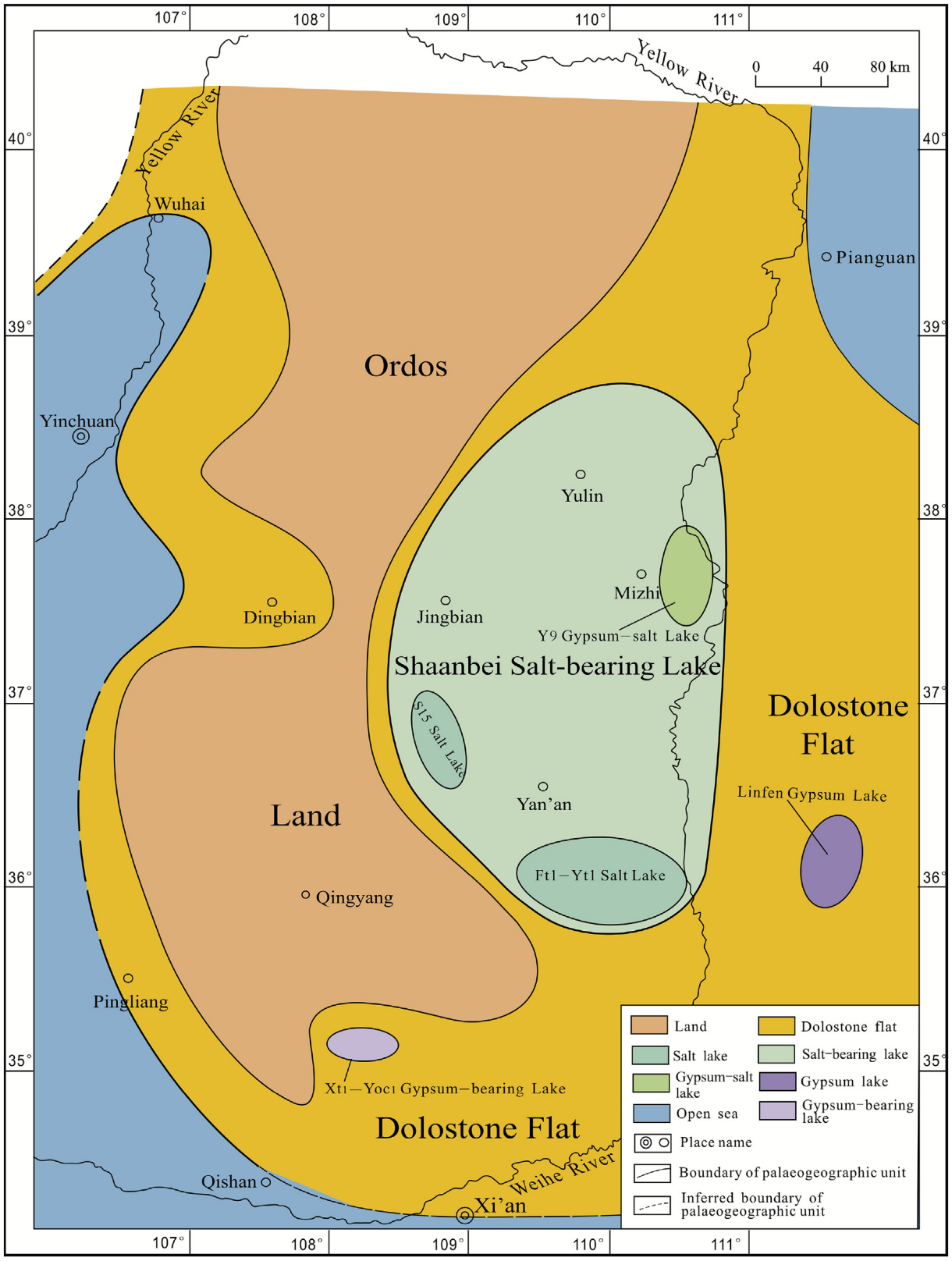


**Fig. 12 – Palaeogeographic map of the Early Ordovician Majiagou Age 1 of Ordos in North China (modified from Feng *et al.*, 2014).**

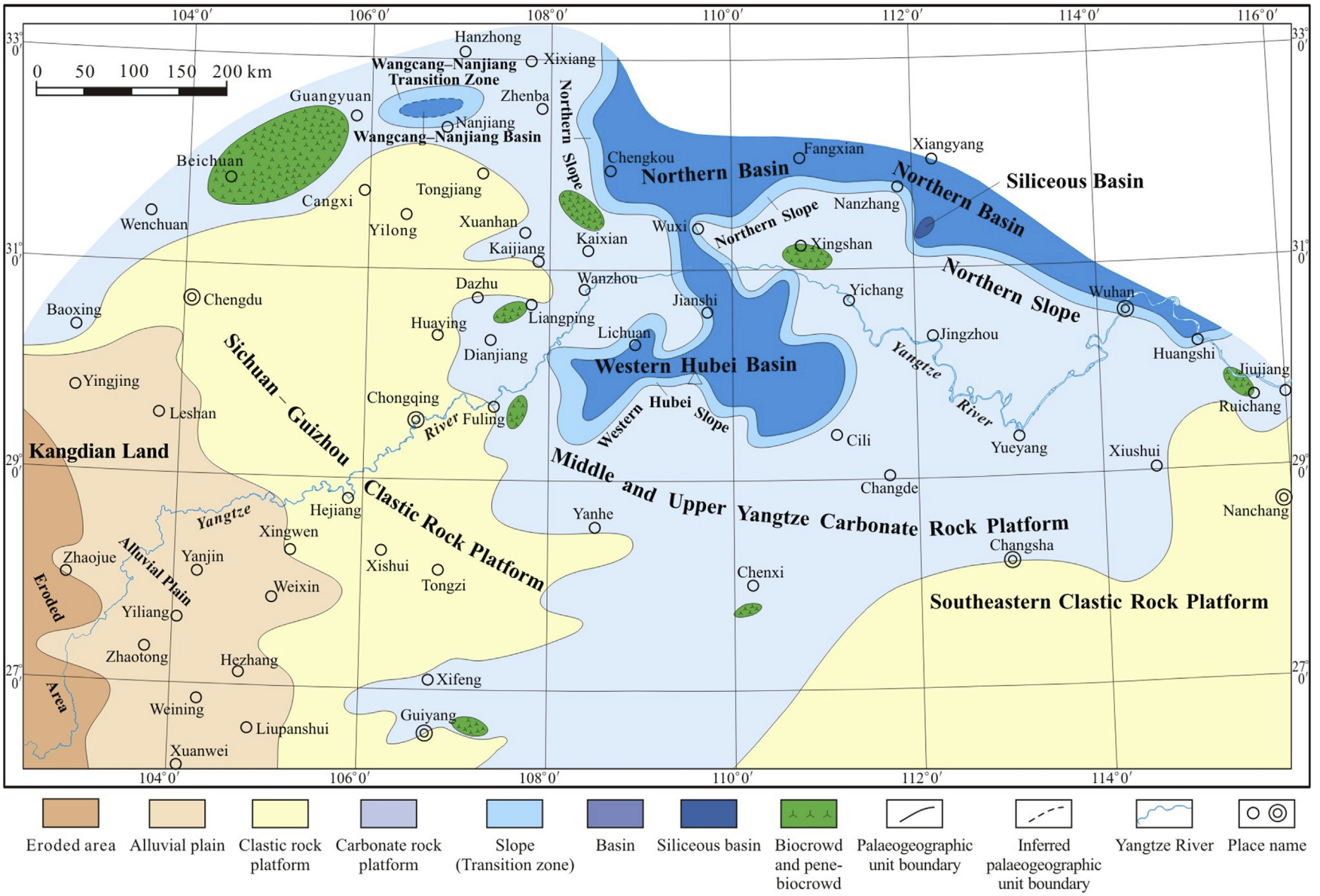


**Fig. 13 – Palaeogeographic map of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China (modified from Luo *et al.*, 2014).**

4) Another method to define sparry bank and limemud bank

In another method, we can utilize the "sparry grain limestone" and "limemud grain limestone" instead of the "grains with sparry calcite cement" and the "grains with limemud matrix" (Feng *et al.*, 2014, 2015a).

According to the isoline map of content (%) of the sparry grain limestone, we can define the areas of content of this limestone ≥50%, 49%–30% and 29%–10%, as sparry bank, sparry penebank and sparry embryonic bank.

According to the isoline map of content (%) of the limemud grain limestone, we can define the areas of content of this limestone ≥50%, 49%–30% and 29%–10%, as limemud bank, limemud penebank and limemud embryonic bank.

To utilize the sparry grain limestone and limemud grain limestone may be much easier but more sketch than to utilize the grains with sparry calcite cement and the grains with limemud matrix.

Here, please pay attention that the fossil fragments mentioned above are transported and eroded. They don't include the biograins *in situ*.

#### 4.3.2. *To define biocrowd*

The biograins *in situ* or fossil fragments *in situ* are the fragments of living beings that lived, died, disintegrated, accumulated and buried in a same water body with low energy, therefore they are coexisted with limemud.

Feng *et al.* (1994a, 1997a, 2014) defined the areas of content of biograins *in situ* ≥50% and 49%–30%, as biocrowd and penebiocrowd.

According to content (%) data of biograins *in situ* of 54 sections (13 first order outcrop sections, 22 second order outcrop sections, 12 third order outcrop sections, 6 first order well sections, 1 second order well section), the isoline map of content (%) of biograins *in situ* of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China was composed (Fig. 9).

In Fig. 9, there is one area (green color area) in which the biograins content is ≥50%, and there are 8 areas (light green color areas) in which the biograins content is 49%–30%. We can define the former one area as biocrowd and the latter 8 areas as penebiocrowds (Fig. 9).

The biocrowds are different from sparry banks and limemud banks, because these biocrowds are formed in water body with totally low energy.

These biocrowds are mainly formed in carbonate platform.

If the content of these biograins *in situ* ≥70%, the biocrowd can be called as biostrome.

#### 4.3.3. *To define dolostone flat and mud flat*

In carbonate platform, mainly in the peripheral area of the old-aged old land, the penecontemporaneous dolostone and mudstone are frequently developed.

According to the isoline map of content (%) of penecontemporaneous dolostone, we can define the area (yellow area) of content of penecontemporaneous dolostones ≥50% as dolostone flat (Fig. 10).

In Fig. 10, the dolostone flat was a large area flat, *i.e.*, Circum-land Dolostone Flat; but in Fig. 11, the dolostone flats were isolated flats with small area.

In the peripheral area of the old-aged old land in which the mudstone developed, we can define the area of content of mudstone ≥50% as mud flat.

In the Early Cambrian Maozhuang Age and around the North China Land, the mud flat was extraordinarily developed (Feng *et al.*, 1990, 2004).

If in the peripheral area of the old-aged old land, the area with mudstone content ≥50% and with penecontemporaneous dolostone content 49%–25%, can be defined as dolomitic mud flat.

If in the peripheral area of the old-aged old land, the area with penecontemporaneous dolostone content ≥50% and with the mudstone content 49%–25%, can be defined as muddy dolostone flat.

#### 4.3.4. *To define halite lake and gypsum lake*

In carbonate platform, sometimes, the halite and gypsum developed.

In the isoline map of content (%) of halite, we can define the areas of content of halite ≥30% and 29%–10%, as halite lake and halite-bearing lake.

In the isoline map of content of gypsum, we can define the areas of content (%) of gypsum ≥30% and 29%–10%, as gypsum lake and gypsum-bearing lake.

If the halite lake and gypsum lake coincided with each other, it can be called halite–gypsum lake.

In Fig. 12, we can see these lakes.

#### 4.3.5. *To define reef*

In carbonate platform, sometimes there were reefs.

According to the location of reefs, the distribution map of reefs can be composed.

#### 4.3.6. *Interim summary*

As mentioned above (4.3.1–4.3.5), according to the isoline map of content (%) of grains with sparry calcite cement or with limemud matrix, and the isoline map of content (%) of sparry grain limestones or limemud grain limestones, we can define the different banks; according to the isoline map of content (%) of biograins *in situ*, we can define the different biocrowds; according to the isoline map of content (%) of penecontemporaneous dolostone and the content (%) of mudstone, we can define the different flats; according to the isoline map of content (%) of halite and the isoline map of content (%) of gypsum, we can define the different lakes; and according to the location of reefs, we can compose the distribution map of reefs.

Sometimes, in palaeogeographic map, in lands and platforms, there were some subunit basins; in basins, there were some subunit lands or platforms; between platforms and seas, there were slopes. All of these subunits can be defined according to the reliable data and relevant preparatory maps.

Up to now, we not only can define the first order palaeogeographic units (old lands and old seas) and the second

order palaeogeographic units (platforms, slopes, basins and troughs), but also can define the third order palaeogeographic units (banks, biocrowds, flats, lakes, and reefs). It means that we can compose the palaeogeographic map basically.

This is the third step of palaeogeographic mapping.

### 4.4. *Overall examination, comprehensive judgement, discarding the dross and selecting the essential, discarding the false and retaining the true*

As mentioned above (4.1–4.3), on the basis of the "Single factor analysis and multifactor comprehensive method —— Methodology of quantitative lithofacies palaeogeography" initiated by us, and according to the reliable and representative data and relevant preparatory maps, we defined the first, second and third order palaeogeographic units and composed the palaeogeographic maps step by step.

Are these palaeogeographic maps qualified?

The proverb said: "**Ninety miles are only half of a hundred miles journey**".

The fourth step of palaeogeographic mapping, *i.e.*, overall examination, comprehensive judgement, discarding the dross and selecting the essential, discarding the false and retaining the true, is the last ten miles.

The first is to examine the reliability and representation of data in all isoline maps, *i.e.*, to examine whether the isoline maps are "mapping based on their data" or not.

The second is to examine the rationality or the regularity of the isoline maps, especially the key isolines to define the relevant palaeogeographic units.

The third is to superpose all isoline maps and to examine and judge the relationship between the palaeogeographic units, to examine and judge whether the palaeogeographic units are coordinated with each other or not, and especially to examine and judge the contradictions between them.

In general, as long as the data in these isoline maps are reliable and representative, the methodology of composing the isoline maps is effective, and we utilized the methodology with more caution, these palaeogeographic units should be basically reliable.

If the reliability and representation of data and these isoline maps are with some problems, and then the palaeogeographic units will be also with some problems, such as some discordances and even some contradictions. In this conditions, we will utilize the words of Mao (1937) "discarding the dross and selecting the essential, discarding the false and retaining the true", to modify some palaeogeographic units or even to discard them.

It is not abnormal that there are some problems in palaeogeographic mapping. We should modify some palaeogeographic units and even cancel them, and therefore ensure that the palaeogeographic map is reliable and qualified.

This is the fourth step of palaeogeographic mapping.

In conclusion, on the basis of the reliable and representative data of sections of the stratigraphic unit in a study area, utilizing the "Single factor analysis and multifactor comprehensive mapping method —— Methodology of quantitative lithofacies palaeogeography", via the above four steps, we can compose the qualified palaeogeographic maps.

This mapping method can be called the "4 steps mapping method".

It is the development of the "Single factor analysis and multifactor comprehensive mapping method —— Methodology of quantitative lithofacies palaeogeography".

### 4.5. *3 palaeogeographic maps*

The following 3 palaeogeographic maps, *i.e.*, the palaeogeographic map of the Early Age of Early Ordovician in South China (Fig. 11), the palaeogeographic map of the Early Ordovician Majiagou Age 1 of Ordos in North China (Fig. 12), and the palaeogeographic map of the Late Permian Wujiaping Age of Middle and Upper Yangtze River Region in South China (Fig. 13), were composed by this "4 steps mapping method".

Certainly, there are problems and shortcomings in these palaeogeographic maps. Criticisms and corrections will be welcome.

These 3 palaeogeographic maps are that of mainly marine stratigraphic units which are mainly composed of carbonate rocks.

About the palaeogeographic mapping of mainly terrestrial stratigraphic units, the author do not dare to say more words, because I have no more practice on it.

But, I have to say one point:

The palaeogeographic mapping of mainly terrestrial stratigraphic units must be based on their reliable and representative data, *i.e.*, each palaeogeographic unit in palaeogeographic map must be based on its reliable and representative data. It is the precondition for palaeogeographic mapping of any kind of stratigraphic unit. If without the reliable and representative data, any distinguished geologist and any distinguished methodology can't compose a qualified palaeogeographic map. It is that "**the cleverest housewife can't cook a meal without rice**".

### 4.6. *Whole and part, strategy and campaigns and tactics*

Mao (1936) said: "**The task of the science of strategy is to study those directing laws that govern a war as a whole. The task of the science of campaigns and tactics is to study those directing laws that govern a partial war. … An understanding of the whole can facilitate the handling of the part.**"

The task of palaeogeographic mapping is also a "war". It is a "scientific research war" to study and reconstruct the characteristics, distribution and evolution of the old lands and old seas and their subunits in geological history periods and human history periods.

The "Single factor analysis and multifactor comprehensive mapping method —— Methodology of quantitative lithofacies palaeogeography", *i.e.*, the "4 steps mapping method", is our strategical law that governs our palaeogeographic mapping as a whole. We utilized this strategical law, on the basis of reliable and representative data, via various preparatory maps, composed the first order, second order and third order

palaeogeographic units, step by step, or one campaign after another campaign, and then finally composed the qualified palaeogeographic map.

Mao (1936) also said: "**People with the experience of the parts, experience of campaigns and tactics, can understand matters of a higher order provided they are willing to think hard.**"

The experience includes success experience and failure experience, the failure experience may be more valuable. Our palaeogeographic mapping methodology was initiated and set up on the basis of hard thinking of the success experience and failure experience, especially the failure experience of our palaeogeographic mapping.

I hope and believe that the palaeogeographers with the experience of palaeogeographic mapping, if they are willing to think hard, should understand the strategical low of the palaeogeographic mapping that governs the palaeogeographic mapping as a whole, and create some new methodologies.

## 5. Nomenclature of palaeogeographic unit in palaeogeographic map

After the palaeogeographic map was composed, the nomenclature of the palaeogeographic units in palaeogeographic map will be an important task.

### 5.1. *Principle of nomenclature*

The principle of nomenclature of each palaeogeographic unit in a palaeogeographic map is very simple, *i.e.*, the name of palaeogeographic unit must match its reality.

### 5.2. *3 components*

The name of palaeogeographic unit in palaeogeographic map consists of 3 components, *i.e.*, the basic name, the present place name and the lithological characteristics.

#### 5.2.1. *Basic name*

The basic names of first order palaeogeographic units are land and sea.

The basic names of second order palaeogeographic units are platform, basin (or trough) and slope.

About the basic names of second order palaeogeographic units, I utilize the relative names, *i.e.*, the platform, slope and basin, instead of the present physical geographic names, such as shelf, continental slope and deep sea. Because the palaeogeographic names (platform, slope, basin and trough) are not totally identical with the present physical geographic names (shelf, continental slope and deep sea).

The basic names of third order palaeogeographic units are mainly bank, biocrowd, flat, lake and reef. Sometimes, there are subunit land, subunit platform and subunit basin in basin, there are subunit land and subunit basin in platform. All of these palaeogeographic subunits are third order palaeogeographic units.

#### 5.2.2. *Present place name*

The present place names are the present regional names or present city names.

In first order and second order palaeogeographic units, the present regional names are necessary, such as the Kangdian Land, the Ordos Land, the Yangtze Platform, the Southeast Platform, and the Jiangnan Basin, *etc.*

#### 5.2.3. *Lithological characteristics*

The lithological characteristics are mainly rock features or rock names.

In second order and third order palaeogeographic units, the present city names and the lithological characteristics are necessary, such as the Yangtze Carbonate Rock Platform (or Yangtze Carbonate Platform), the Southeast Clastic Rock Platform (or Southeast Clastic Platform), the Jiangnan Shale Basin; the Chengkou Bank, the Wuxi Bank; the Bijie Dolostone Flat, the Guiyang Dolostone Flat, *etc.*

In general, the nomenclature of each palaeogeographic unit in a palaeogeographic map is important but uncomplicated. As long as we adhere to the principle that the name must match its reality, the nomenclature may be simple.

However, there appeared some problems.

### 5.3. *Problems of nomenclature*

There are problems in nomenclature of the palaeogeographic unit in a palaeogeographic map. The following are some examples.

1) Example 1

In the southern Guizhou Province of South China and in the Early Triassic, there was a small carbonate platform, *i.e.*, the Luodian Carbonate Platform. Since this platform was located in a broad deep water basin, *i.e.*, the Guizhou–Guangxi–Hunan Basin, it can be called as an isolated Luodian Carbonate Platform.

But, some geologists (Lehrman, 1993; Lehrman *et al.*, 1998) called the small isolated Carbonate Luodian Platform as the "Great Bank of Guizhou". Up to now, this term "Great Bank of Guizhou" has been cited in more than 300 articles in foreign countries.

In 1990s, Feng *et al.* studied the lithofacies palaeogeography of the Early and Middle Triassic in South China. According to our geological data (Feng *et al.*, 1994b, 1997b), in the Early Triassic and in the southern Guizhou Province, there was only a small isolated Luodian Carbonate Platform, but there was no "Great Bank of Guizhou". The "Great Bank of Guizhou" was not consistent with the principle of nomenclature of palaeogeographic unit, *i.e.*, the name did not match its reality. So, **the term "Great Bank of Guizhou" should not be used any more**.

I and my colleagues of the editorial office of *Journal of Palaeogeography* have written an English article *There was no "Great Bank of Guizhou" in the Early Triassic in Guizhou Province, South China* (Feng *et al.*, 2015a) and a Chinese article *About the "Great Bank of Guizhou"* (Feng *et al.*, 2015b). They were

published in *Journal of Palaeogeography* (English Edition and Chinese Edition) respectively. In fact, the latter is a detailed abstract of the former. We hope the articles can encourage the discussion and contention among the geologists worldwide, and thus can promote the development of palaeogeography.

2) Example 2

In an article (Mou *et al.*, 2014) published in the *Journal of Palaeogeography* (Chinese Edition), the authors called the "old land" as "uplift" or "palaeo-uplift". The "uplift" or "palaeo-uplift" is a term of palaeotectonics or tectonopalaeogeography. There are two kinds of "uplift" in the old sea, *i.e.*, the uplift above the water surface of the old sea, and the uplift under the water surface of the old sea. The former was an old land, and the latter was a highland in the old sea. Therefore, the article's authors should define these two kinds of "uplift" clearly.

3) Example 3

In an article (Chen *et al.*, 2014) published in the *Journal of Palaeogeography* (Chinese Edition), the authors called the "old land" as "palaeo-uplift", "palaeo-eroded area", "palaeo-exposed area", but they did not give definitions to these terms. In my judgement, it may be difficult for the article's authors to give concrete definitions to these terms, because they did not have sufficient reliable data.

4) Example 4

In an article (Li and He, 2014) published in the *Journal of Palaeogeography* (Chinese Edition), in the palaeogeographic map of the Early Cambrian Qiongzhusi Age of Sichuan Basin and adjacent areas, the authors marked the same palaeogeographic unit with two names, *i.e.*, the "Clastic Platform" and "Intracratonal Depression Basin". The former is a term of palaeogeography and the latter is a term of tectonic geology. In palaeogeography, the "platform" and "basin" are with totally different meanings. But, these two terms with totally different meanings are marked in the same palaeogeographic unit. It is unsuitable.

Similar problems also occur in this article, such as in another palaeogeographic map, the authors marked the same palaeogeographic unit with two names, *i.e.*, the "Dolostone Flat" and "Intracratonal Depression Basin". It is also unsuitable.

## 6. Explanation of each palaeogeographic unit in palaeogeographic map

The explanation of each palaeogeographic unit in a palaeogeographic map is the important content of palaeogeographic map and palaeogeographic article which was written on the basis of this palaeogeographic map.

The explanation of each palaeogeographic unit includes:

(1) The mapping data of each palaeogeographic unit.

It is the foothold of each palaeogeographic unit and palaeogeographic map. If the mapping data have been mentioned in the relevant isoline maps, the data explanation of the palaeogeographic units can be simple or even omitted. If the mapping data of some palaeogeographic units have not been mentioned above in the relevant isoline maps, they must be stated in detail in the explanation of these palaeogeographic units.

(2) The characteristics of each palaeogeographic unit.
(3) The relationship between the palaeogeographic unit and its adjacent palaeogeographic units.
(4) The evolutional relationship between the palaeogeographic unit and its original unit in past geological periods, if it is possible.

In a palaeogeographic map, the problem of explanation of each palaeogeographic unit is reduced or even no explanation.

It may be that the original reliable data of the palaeogeographic unit in the articles were not sufficient.

The explanation of each palaeogeographic unit in palaeogeographic map is the description of objective reality of the unit. It is different from the explanation of significance of palaeogeographic map and palaeogeographic article which was written on the basis of palaeogeographic map.

About the explanation of significance of palaeogeographic map and palaeogeographic article, please see the following section.

## 7. Explanation of significance of palaeogeographic map and palaeogeographic article

The explanation of the significance of a palaeogeographic map and palaeogeographic article which was written on the basis of palaeogeographic map includes theoretical significance and industrial significance. The significance of the palaeogeographic map and article is necessary to explain.

But, we have to be aware that the palaeogeographic article is written on the basis of palaeogeographic map. Therefore, the palaeogeographic map is the first, and the palaeogeographic article is the second. If without the palaeogeographic map, the palaeogeographic article will be a river without source and a tree without root, and it will become an idle talk. It is the relationship between the palaeogeographic map and palaeogeographic article.

In addition, we have to be aware that the theoretical and industrial significance of the palaeogeographic map and article is determined by objective geological practice and industrial practice, and is not determinate by the subjective desire of the authors. Therefore, about the explanation of significance of palaeogeographic map and palaeogeographic article, we should be with caution, *i.e.*, we should know when and where to stop, and should not be overstated.

However, in some articles published in the *Journal of Palaeogeography* (Chinese Edition and English Edition), some authors were overstated.

For example, in an article of Vérard *et al.* (2015) with the title of *3D palaeogeographic reconstructions of Phanerozoic versus sea-level and Sr-ratio variations* (*Journal of Palaeogeography*, 2015, 4(1): 64–84), the authors proposed a new model to reconstruct

the altitude of old lands and the water depth of old seas of **anywhere on the globe and at any geological time**.

This new model is very interesting and stimulated my deep thinking.

I am not a tectonic geologist and unfamiliar with Sr-ratio and the new model, and thus it is difficult for me to point out some concrete questions. But, I know the difficulty of the task to reconstruct the altitude of old lands and the water depth of old seas of anywhere on the globe and at any geological time.

I have presented my book *Lithofacies Palaeogeography of the Cambrian and Ordovician in China* to Dr. Vérard, and hope that Vérard et al. can reconstruct the altitude of the Cathaysian Land and North China Land and the water depth of their peripheral old seas of the Cambrian and Ordovician in China. About these two old lands, I can only qualitatively state that the North China Land was an old-aged peneplained old land and its peripheral sea was mainly a carbonate platform sea; the Cathaysian Land was a young-aged old land with steep topography and provided nearly 20,000-m-thick clastic sediments for the Southeast Clastic Platform sea on its western side. I can't quantitatively determine the altitude of these two old lands and the water depth of their peripheral old seas. Because I have not an effective methodology.

I have written an article *Hope to be from model to practice — Words of the Editor-in-Chief* (*Journal of Palaeogeography*, 2015, 4(1): 63), and hope that Dr. Vérard et al. can utilize their new model to solve the problem, *i.e.*, can reconstruct the altitude of the Cathaysian Land and North China Land and the water depth of their peripheral old seas of the Cambrian and Ordovician in China, and make a great contribution to the palaeogeography of China (Feng, 2015a).

It is a great but very difficult task. This task may be or even may not be accomplished through the hard work of geologists worldwide of several generations.

Therefore, it is obvious an overstatement.

However, as the Editor-in-Chief of *Journal of Palaeogeography* and with the principle of "**A hundred flowers blossom and a hundred schools of thought contend**", I have approved this article to be published in *Journal of Palaeogeography*, because this article is "a flower" with academic significance and the words of "a school of thought". We can utilize it as a chance to launch an academic discussion and contention and thus promote the development of palaeogeography.

The two articles of *3D palaeogeographic reconstructions of Phanerozoic versus sea-level and Sr-ratio variations* and *Hope to be from model to practice* aroused enthusiastic response among the geologists worldwide.

Profs. G. Shanmugam and A. J. van Loon wrote discussion articles respectively at once (Shanmugam, 2015; van Loon, 2015). Dr. Vérard wrote a reply article also (Vérard, 2015). I, as the Editor-in-Chief, wrote an article to review the above 3 articles and the Vérard's first paper (Feng, 2015b).

These 4 articles have published in the column "Academic discussion" in the *Journal of Palaeogeography* (Vol. 4, No. 3, 2015). I hope that more readers worldwide will participate in this academic discussion and promote the development of palaeogeography.

## 8. Evaluative standards of palaeogeographic map and palaeogeographic article and book

The evaluative standards of the palaeogeographic map and palaeogeographic article and book which are written on the basis of palaeogeographic map are as follows:

(1) The reliable and representative data are the first necessary. The determination and drawing of each palaeogeographic unit in the palaeogeographic map must be based on its data. It is the most important.
(2) An effective methodology is indispensable.
(3) The name of each palaeogeographic unit in the palaeogeographic map must match its reality.
(4) The explanation of each palaeogeographic unit in palaeogeographic map should be sufficient and should not be without.
(5) The explanation of the theoretical and industrial significance of the palaeogeographic map and palaeogeographic article and book should be with caution and should not be overstated.

Are these standards overtopped or over-critical?

In my mind, these standards are neither overtopped nor over-critical, they are the fundamental standards for evaluation of palaeogeographic map and palaeogeographic article.

We should utilize these standards to examine and evaluate the palaeogeographic maps and articles which were written on the basis of the palaeogeographic map.

## 9. Self-evaluation

If I evaluate others, I should evaluate myself.

Are the palaeogeographic maps in this article and this article itself conformed to the above 5 evaluative standards?

Are our published articles and books that are written on the basis of our palaeogeographic maps conformed to the above 5 evaluative standards?

The following is my answer.

(1) The palaeogeographic maps of myself and my research team are composed on our data (firsthand data and secondhand data). The determination and drawing of each palaeogeographic unit in our palaeogeographic maps is based on its data.
(2) Our palaeogeographic mapping methodology is the "Single factor analysis and multifactor comprehensive mapping method", *i.e.*, the "4 steps mapping method". All of our preparatory maps and palaeogeographic maps can be reexamined.
(3) In our palaeogeographic maps, the name of each palaeogeographic unit is matched with its reality.
(4) In our palaeogeographic maps, the explanation of each palaeogeographic unit is based on its data.
(5) The explanation of theoretical and industrial significance of our palaeogeographic maps and palaeogeographic articles and books which are written on the

basis of our palaeogeographic maps are with caution and not be overstated.

The above (1)–(4) mainly reflect the reliability of our palaeogeographic maps. I can only say that our palaeogeographic maps are composed on their data and they are basically reliable. I don't dare to say that our palaeogeographic maps are totally reliable, because our data (firsthand data and secondhand data) are not sufficient enough, and our methodology may be to call in questions.

The above (5) mainly reflects the academic level of our palaeogeographic maps, articles and books. Our palaeogeographic maps, articles and books have made contribution to the development and foundation of quantitative lithofacies palaeogeography and are useful in the prediction and exploration of mineral resources, especially of oil and gas.

In a word, our palaeogeographic maps are composed on their data, our palaeogeographic articles and books have made contribution to the development and innovation of palaeogeography, and they are useful to industrial practice. They can be evaluated by myself as "**pass**", or as inadequately "**good**", but far from "**excellent**".

I hope to see the excellent palaeogeographic maps and excellent articles and books that are written on the basis of the excellent palaeogeographic maps.

## 10. To take responsibility for authors, readers and human society

The *Journal of Palaeogeography* (Chinese Edition and English Edition) undertakes a heavy task to promote the development and innovation of Chinese and international palaeogeography. The articles published in the two journals not only belonged to the authors themselves, but also belonged to the readers and human society. Therefore, the authors should utilize the 5 evaluative standards to examine and complete their articles, and take the responsibility for readers and human society. The editors of *Journal of Palaeogeography* also should utilize the 5 evaluative standards to review, edit and publish the articles, and also take the responsibility for the authors, readers and human society. I, as the Editor-in-Chief, must take the responsibility for the authors, readers and human society.

To compose a qualified palaeogeographic map and to write a qualified palaeogeographic article and book are the "thousands years task". It should be with caution and caution.

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The primary Chinese manuscript of the article *Problems of palaeogeographic researches* and *palaeogeographic mapping* was specially reported in a palaeogeographic symposium in the 13th National Conference of Palaeogeography and Sedimentology that was held by China University of Mining and Technology (Beijing), October 2014, in Beijing, China. It aroused an enthusiastic discussion.

On the basis of the comments and suggestions of the attendees at the symposium, I rewrote the primary Chinese and English manuscripts and the article's name was changed to *On palaeogeographic map*.

During the long rewriting course, Mrs. Zheng Xiujuan, Wu Xiaoming, Liu Min, Wang Yuan, the editors of the *Journal of Palaeogeography*, actively supported me in polishing, typewriting, mapping and editing the article.

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